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GEOCHEMICAL CHARACTERISTICS OF KOMATIITE – THOELIITE ASSOCIATION IN PARTS OF DALTONGANJ, PALAMAU DISTRICT, JHARKHAND

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ABSTRACT

In the southern and southwestern part of Daltonganj town, number of ultramafic intrusives (represented by komatiites) and mafic dykes (represented dominantly by amphibolites) are encountered. The komatiites exhibit typical spinifex texture whereas amphibolites retain imprints of igneous texture and chemistry. Chemically, amphibolites exhibit characteristically high Mg-thoeliitic nature. Spatial association of these two rock types suggest that they are genetically linked although they fall in two different geochemical fields. On the basis of various chemical variation diagrams it can be assumed that there is distinct geochemical hiatus between the two groups. High Mg- komatiites are followed by low K-thoeliites.

Key words: Chotanagpur Gneissic Complex, Amphibolites, Komatiites, Thoeliites, Semra-Salatua, Geochemistry.

INTRODUCTION

The Chotanagpur Gneissic Complex (CGC), basement rocks of the Eastern Indian Shield, has been traversed by numerous ultramafic to mafic dykes occurring in the form of komatiite to amphibolite and some dolerite. The information regarding these dykes is scanty (Ghose *et al.*, 2005; Ghose and Chatterjee, 2008). Most of these dykes are Precambrian in age as they do not traverse through the overlying Permian – Gondwana Sequence (Mahadevan, 2002; Kumar and Ahmed, 2007). In the present work geochemical characteristics of rarely occurring ultramafic rocks in the form of komatiite and its intimately associated mafic dykes (represented mainly by amphibolites) occurring SW of Daltonganj town has been studied to understand their nature, source and possible genetic link.

GEOLOGICAL SETTING OF THE STUDY AREA

The Eastern Indian Shield consists of two major crustal provinces viz Singhbhum crustal province and Chotanagpur gneissic province (Ghose, *et al.*, 2005). The Singhbhum Proterozoic basin has a tectonic boundary with the northern

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high grade metamorphic migmatite belt of C.G.C. trending parallel to the basinal axis (Bose, 1990). It consists more than ninety percent of the Archaean rocks dominated by granites, gneisses and migmatites. The pre- tectonic igneous activity is characterised by small bodies of ultramafic intrusions. The country rocks were folded and metamorphosed during the Satpura Orogeny (900 ± 200Ma ; Gupta, 1973; Ghose, 1983, 1992). The rocks of the C.G.C. have undergone predominantly amphibolite facies metamorphism (Mahadevan, 2002). It has been observed that the metamorphic grade decreases from north towards south in the C.G.C. (Banerjee, 1991) and western part to the eastern part (Bhattacharya, 1976). However, this seems to be only a broad generalisation because of comprehensive view of metamorphic grade has not emerged due to the lack of geochronological data and systematic regional evaluation.

Geologically the C.G.C. is an extension of the Satpura region including Sausar Group of Central India based on the continuance of ENE-WSW strike of the formation (Holmes, 1955; Saha, 1994; Mahadevan, 2002; Acharyya, 2001). Based on the lithological similarities and spatial disposition (Singh, 1988) proposed a correlation of the formations of the C.G.C. with those from Singhbhum on one hand and with the formation of Central India and Rajasthan on the other (Fig.1).

The metasedements and gneissic rocks of the study area have been intruded by ultrabasic dyke in the form of Peridotitic komatiite and metabasic rocks represented by amphibolites and metadolerites. Among the metabasic rocks amphibolites are predominant. These mafic and ultramafic intrusives preceded the major granitic activity at 1600 Ma (Pandey *et al.*, 1986) as evident from the occurrence of the former as enclaves within the latter. The general trend of these mafic-ultramafic rocks are almost NW-SE. These rocks are generally concordant with the foliation of the host rocks, though local discordance is not uncommon. Large number of these bodies are a few cms in thickness and metres to decametre in dimension thus they are far below the mappable dimensions and therefore remain unrepresented in most geological map (Mahadevan 2002).

PETROGRAPHY

The amphibolites of the study area are dark green to black, very hard and massive, medium to coarse grained rocks. Some amphibolites are foliated with fabric defined by aligment of hornblende and banded with amphibole and feldspar rich layers. The rock contains hornblende, plagioclase feldspars, pyroxenes, biotite, and magnetite. Plagioclase occur both as phenocrysts and groundmass. Augite is the dominant pyroxene which occurs as euhedral to subhedral phenocrysts. Ophitic to sub-ophitic relationship between plagioclase and clinopyroxene phenocrysts is common. Plagioclase grains are often saussuritised and biotite retrograde reaction rim is present around amphiboles.

Komatiites are hard, compact massive rocks and occur as lenses and enclaves having a concordant trend with the foliation of the country rocks. The rocks is characterised by microspinifex texture exhibited by array of closely spaced and parallel bladed or plate like crystals of olivine (with marked alteration to serpentine) and clino and orthopyroxenes. Primary interlocking mosaic and original crystal boundaries of olivine and pyroxene are well preserved in spite of slight alteration of these two minerals to secondary hydrous minerals. The rock is also characterised by complete absence of plagioclase establishing its formation beyond stability limit of this mineral and presence of euhedral crystals of isotropic pleonaste.

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KOMATIITE SUITE – A REVIEW

In most of the Precambrian areas, the geochemical data obtained from komatiite suite of rocks indicate that they show a general range in composition from highly magnesian rocks with greater than 30% MgO to less than 10% MgO. The latter variety is termed as magnesian thoeliite. Viljoen and Viljoen (1969) have coined the term high magnesian ultramafic rocks (MgO >40% as peridotitic komatiite (PK) and the low magnesian basic rocks as basaltic komatiite (BK). Low alumina and high CaO/ Al_2O_3 ratios (Av.1.59) were characteristic features for all the members of the komatiite suite implying a genetic link between the basaltic and peridotitic members Arndt *et al.* (1977) classified komatiite into three categories viz peridotitic komatiites (MgO>20 wt%), (2) pyroxentic komatiites (MgO between 12 and 20 wt%) and (3) basaltic komatiites (MgO <12 wt%).

GEOCHEMISTRY

Based on the petrographic study, 13 number of samples (8 no. Of komatiite and 5 of amphibolites) were selected for major and trace element analysis. Freshest part of the samples was chipped out and powdered until it was passed through 330 ASTM Mesh. Major and trace elements were determined using XRF (Phillips PW 1450/20 sequential automatic X-ray Fluorecence Spectrophotometer) and ICP-MS (Perkin Elmer) at Research and Development Centre for Iron and Steel, SAIL, Ranchi. Basalt and diabase standards were used to prepare caliberation curves. The precision of the chemical analysis is better than 5% for the major elements and $\pm$ 10% for the trace elements. FeO was determined by potassium dichromate titration. Loss on ignition (LOI) has been estimated by heating the samples at 950°C for three hours. Major oxides and trace element analyses of both the rock types are presented (Table-1).

Based on the MgO wt% the rocks can be classified into peridotitic komatiite and thoeliites respectively. The metabasics rocks mostly show doleritic textures and indicate thoeliitic chemistry. Their spatial association with peridotitic komatiites in the area suggest that thoeliites represent differentiated members of the same magmatic suites.

From the Table I it is clear that peridotitic komatiite have MgO content varies from 24.48 to 29.1 . The peridotitic komatiite show TiO_2 values of 0.32 to 0.45 wt% and CaO/ Al_2O_3 ranges from 0.73 to 1.35.In contrast to komatiite the associated amphibolites show lower MgO (6.13 to 7.88 wt%).The komatiites and amphibolites fall in two different fields when plotted on MgO-CaO-Al_2O_3 diagram (Fig. 2). Amphibolites show clear thoeliitic affinity whereas komatiites occupy its own field Jensen (1976) suggested the use of Al_2O_3 – $Fe_2O_3^{(t)}$ – MgO. ternary diagram (Fig. 3) to discriminate komatiite series from thoeliitic affinity. The plotting of FeO^t / FeO^t + MgO vs Al_2O_3 of ultramafic and mafic rocks of the area (Fig. 4) also brings out clear distinction between komatiite and thoeliites. Similarly, the major element plots of Al_2O_3 vs MgO and TiO_2 vs MgO (Fig. 5) show differences in chemistry between the two groups. It is clear in the diagram that thoeliitic rocks have a distinctly higher concentraton of TiO_2 / Al_2O_3 compared to associated komatiites. In the (Fig. 6), the TiO_2 vs CaO plots show that the komatiitic rocks exhibit values close to chondrites (CaO / TiO_2 = 17) with few samples scattering away from the chondritic values. The komatiites of the Semra area exhibit similarity with Munro type komatiites (Bhattacharya *et al.* 2010).

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Table-1: Major oxides (in wt%) and trace elements (in ppm). of the Amphibolites south of Daltonganj, Palamau district , Jharkhand

	Massive Amphibolite				
Sample No.	DV/45	DV/52	DV/56	DV/59	DV/61
SiO_2	49.03	49.31	48.86	47.96	46.21
TiO_2	1.75	1.61	1.72	1.66	1.8
Al_2O_3	14.02	15.1	14.2	15.7	15.5
Fe_2O_3	2.28	1.73	1.92	2.91	2.64
FeO	9.19	8.98	10.42	9.94	9.71
MnO	0.09	0.07	0.05	0.06	0.07
MgO	6.13	6.85	7.23	7.88	6.64
CaO	11.08	9.76	9.17	8.74	10.2
Na_2O	2.46	2.27	2.43	2.11	2.51
K_2O	0.2	0.18	0.19	0.16	0.22
P_2O_5	0.51	0.38	0.46	0.42	0.62
Total	96.74	96.24	96.65	97.54	96.12
Trace elements (in ppm)					
Cr	308	342	330	413	280
Ni	279	250	244	265	290

Table 2. Major oxide (in wt%) and trace elements (in ppm)
South of Daltonganj, Palamau district, Jharkhand

Sample No.	DB10	DB13	DB12	DB15	DB18	DB8	DB6	DB5
SiO_2	35.84	34.87	40.65	37.1	35.6	30.2	27.5	28.2
TiO_2	0.4	0.41	0.45	0.39	0.32	0.37	0.48	0.33
Al_2O_3	7.98	7.67	8.58	7.05	6.68	8.4	7.94	8.04
Fe_2O_3	13.06	13.07	11.2	9.9	12.66	18	17.3	20.5
MnO	0.27	0.23	0.14	0.16	0.18	0.24	0.15	0.17
MgO	25.56	27.72	24.48	25.4	29.9	25.1	28	29.1
CaO	10.77	9.5	7.19	9.3	6.6	5.95	8.68	5.88
Na_2O	0.32	0.32	0.09	0.13	0.07	0.14	0.32	0.27
K_2O	0.01	0.52	0.02	0.03	0.02	0.23	0.11	0.17
P_2O_5	0.07	0.06	0.02	0.08	0.05	0.36	0.21	0.22
LOI	6.02	6.7	7.04	9.4	8.22	10	9.02	8.04
Total	100.3	100.84	99.9	98.3	100.4	99.2	99.7	101
Trace element (in ppm)								
Cr	3000	2800	3300	3400	3195	3364	3192	3092
Ni	1650	1520	850	750	1725	1810	1625	1587

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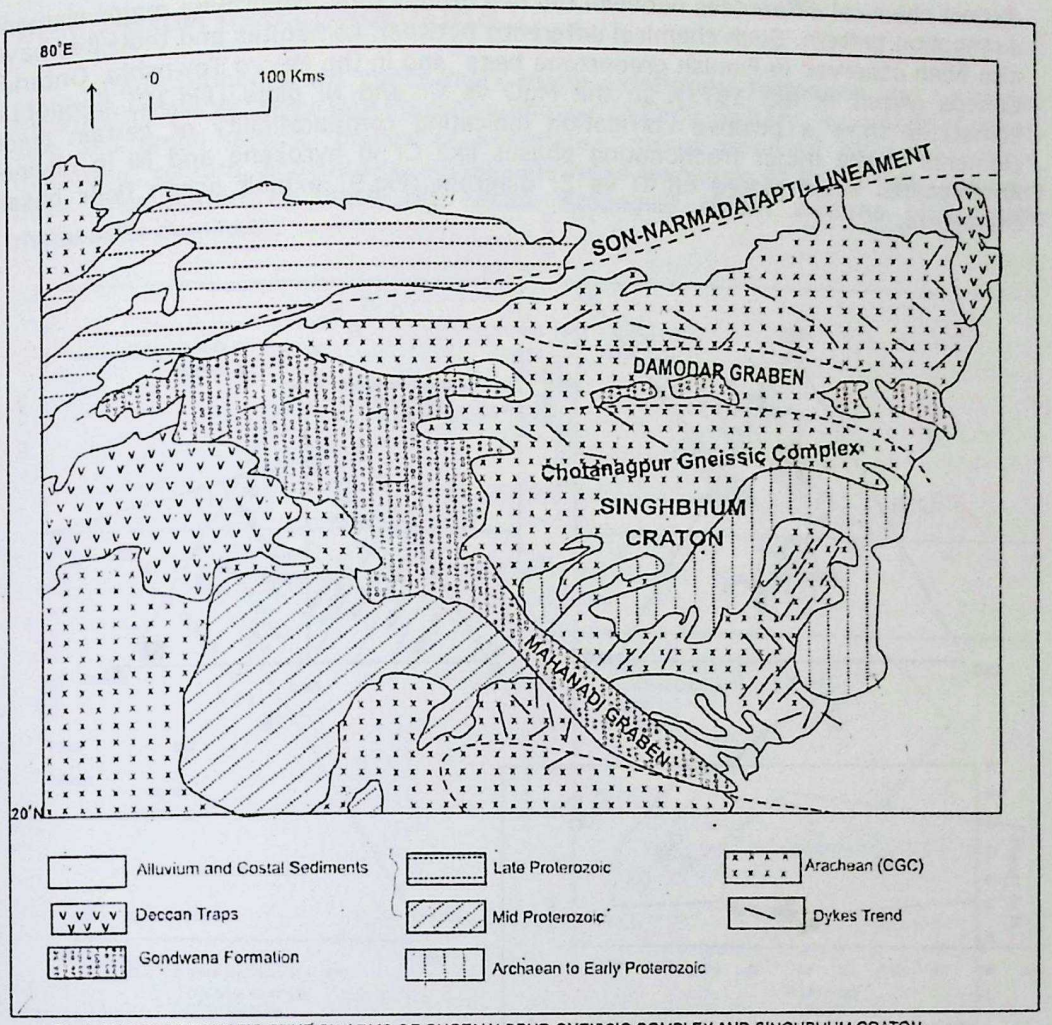

Fig.1: MAFIC ULTRAMAFIC DYKE SWARMS OF CHOTANAGPUR GNEISSIC COMPLEX AND SINGHBHUM CRATON

Nesbett *et al.*(1979) have pointed out that the TiO_2 / CaO and TiO_2 / Al_2O_3 ratios will be affected greatly if the rocks suffered alteration . Petrographic study of komatiites show little alteration to secondary minerals like chlorite, serpentine, talc and tremolite and occasionally secondary carbonate which might influence the bulk chemistry. In the MgO vs Al_2O_3 plot, some samples (Fig.7) show scattering away from the general trend indicating either depletion of Al_2O_3 or addition of Al_2O_3. These samples clearly show effect of alteration. Thin section studies of these samples show presence of chlorite and some hydrous minerals. The mafic rocks when plotted on TiO_2 – P_2O_5 – K_2O diagram (Fig.8 after Pearce and Cann 1973) show oceanic thoeliitic characters.

The trace element data for ultramafic and mafic rocks are given in Table-2 Peridotitic komatiites show higher values of Cr (Av. 3168 ppm) and Ni (Av. 1440 ppm.) when compared to the associated, tholeiites (Av. Cr 335 ppm and Ni 266 ppm). The MgO% vs Cr and Ni plots for peridotitic komatiites and tholeiites show

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distinct chemical differences between the two groups thus, confirming major element distribution pattern. Such chemical difference between komatiites and tholeiites have also been observed in Finnish greenstone belts and in the Munro Township, Ontario, Canada (Arndt *et al.*, 1977). In the MgO vs Cr and Ni plots (Fig.10) peridotitic komatiites show a positive correlation indicating comparatibility of certain trace elements in the major fractionating phases like Cr in pyroxene and Ni in olivine. Amphibolites when ploted on Ti vs Zr diagram (Fig.9) exhibit ocean floor basalt characters.

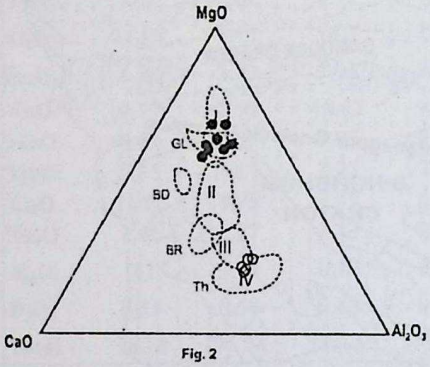

Fig. 2

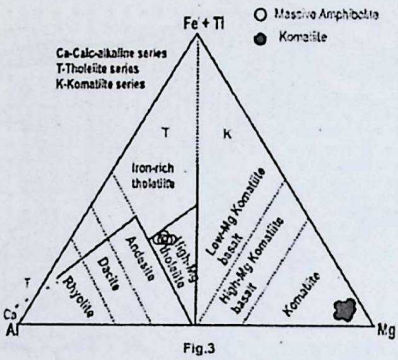

Fig.3

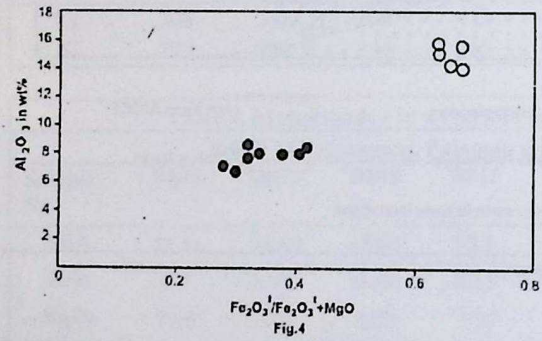

Fig.4

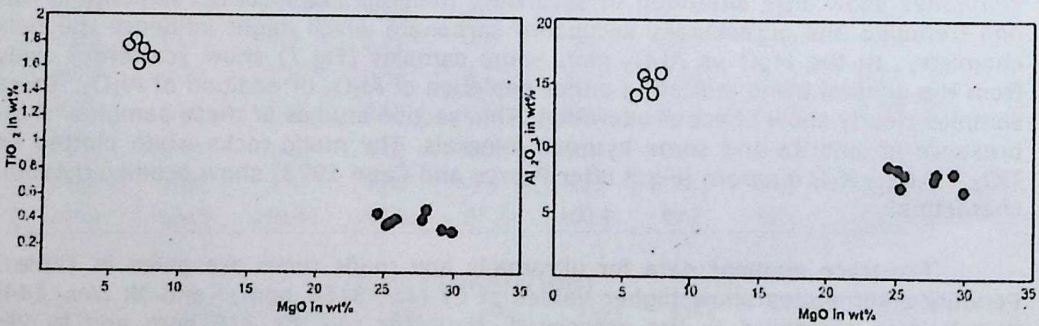

Fig.5

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DISCUSSION AND CONCLUSION

Intracontinental rift zones mark major extensional tectonism and controlled magmatism in CGC since late Palaeoproterozoic to Early Tertiary. A number of dykes, sills and small lensoid bodies of komatiites, metamorphosed ultramafic rocks, metabasic, gabbro, anorthosite, subalkaline rocks belonging to Proterozoic age have been encountered in these rift zones. Amongest these, swarms of thoeliitic metabasics dominate.

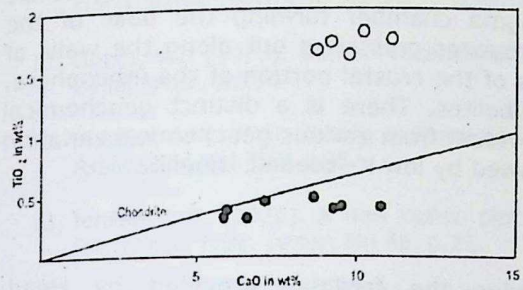


Fig.6

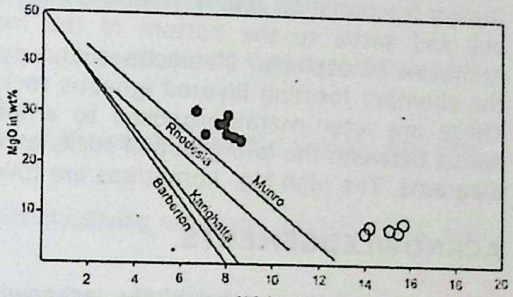
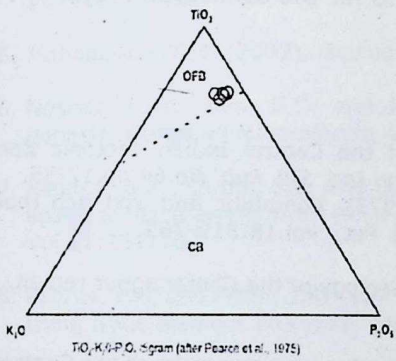


Fig.7



TiO_2-K_2O-P_2O_5 diagram (after Pearce et al., 1975)
OFB-Ocean Floor Basalt
CB-Continental Basalt
Fig.8

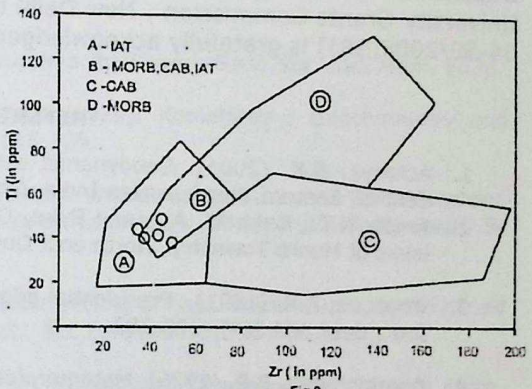
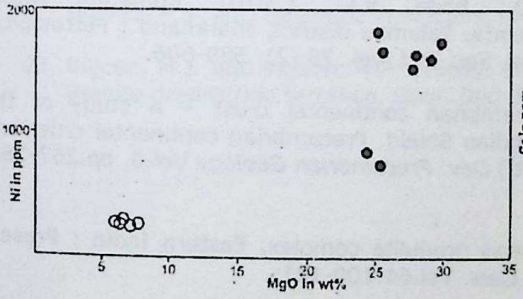


Fig.9



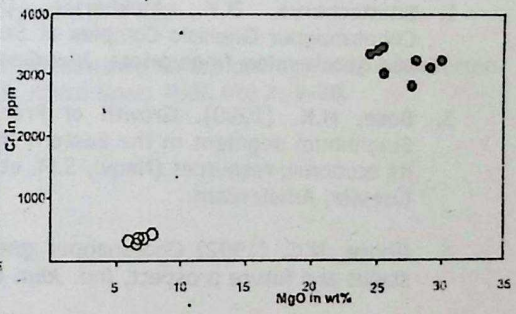


Fig.10

The Proterozoic komatiite-thoeliitic dykes swarms in the study area supposed to be induced by thining and fracturing of the crust as a result of extensional

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tectonism involving shallower depths of the mantle probably not exceeding 250-300 kms. The difference in thermal energy source from the mantle possibly resulted smaller volume of melts on partial melting of mantle in the Proterozoic. Such melts on their upward journey through crustal depths filled the fractures developing dykes/sills and related magmatic bodies generated at different periods in the early history of CGC.

The close spatial association of komatiite - thoeliite rocks points to a common origin of fractional crystallisation of an ultramafic (komatiite) parent at rift system. During fractionation highly refactory components such as olivine, Ni, Cr crystallise out and settle to the bottom of the magma chamber forming the base of the Archaean lithosphere. Plagioclases and pyroxenes crystallise out along the walls of the chamber forming layered igneous rocks of the crustal portion of the lithosphere. These are later metamorphosed to amphibolites. There is a distinct geochemical hiatus between the two group of rocks as evident from various geochemical variation diagrams. The high Mg- komatiites are followed by low K- oceanic thoeliite.

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EVALUATION OF HEAVY METAL LEVELS IN SACHET WATER PRODUCED IN DAMATURU, YOBE STATE, NIGERIA

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ABSTRACT

The concentrations of heavy metals in sachet water samples produced and vended for drinking in Damaturu were analyzed for Al, As, Cr, Cu, Fe, Mn, Pb and Zn, using the WAGTECH international physicochemical water analysis kit. The results obtained indicated that As and Pb were below the detectable limits in all the samples but all the locations showed variations in levels of the other tested heavy metals which occasionally fell above the Nigerian drinking water standards as stipulated by the National Agency for Food and Drug Administration and Control (NAFDAC). However, Fe which ranged between 1.00±0.001 mg/l to 7.00±0.01 mg/l was much higher than the permissible limit of 0.3 mg/l in all the examined samples. Therefore, it is important to monitor the levels of Fe and other heavy metals to meet the NAFDAC drinking water regulatory guidelines to safeguard the lives of the consumers.

Key words: Heavy metals, NAFDAC, Permissible limit, Regulatory guidelines, Sachet water.

1.0 INTRODUCTION

Water is an essential requirement for life and for it to be suitable for drinking and domestic purposes; it must meet the standards set by the World Health Organization (WHO, 2006) and NAFDAC (2004). These standards were set based on the quality of water assessed by carrying out both quantitative and qualitative analyses.

A number of people in the developing countries including Nigeria lack access to potable water though the provision of clean potable water is necessary for good health and in prevention of diseases (FAO, 1997). Since life is impossible without water, people were compelled to accept and use water from whatever source despite the devastating consequences of polluted water on human health. Damaturu like

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quite a number of towns in Yobe state is faced with inadequate supply of qualitative drinking water. The widespread and long lasting water shortages in many areas are as a result of rising demand, unequal distribution of usable fresh water and increasing pollution of existing water supplies. The rural people have less access to good quality water and rely on the available groundwater sources and focus is in most cases on the availability of water rather than the quality of the water.

The thirst for good drinking water led to the fast acceptance of sachet water when it was introduced in Yobe State around 1999. It was happily accepted by both the rural and the urban people due to its handy nature, ready to drink, affordable and assumed to be 'pure', though the quality of such products have been questioned (Adekunle *et al.* 2004; Dada 2009, Waziri, 2012).

The occurrence of elevated levels of trace metals especially in drinking water is a good indication of man-induced contamination and high levels of heavy metals above permissible limits can often be attributed to anthropogenic influences. Heavy metal concentrations in the drinking water may be relatively low and may even meet the water quality criteria, but long-term exposure to the metals could result in the accumulation of high loads of pollutants. Such exposures are known to cause lung cancer, damage kidney and affects central nervous system among other devastating effects (Vahora, 1982;Triphati and Krishmathays (1997); Olajire *et al.* 2003). Negative health effect from low-level exposure to potentially toxic elements has also been reported (Pappas *et al.* 2008).

The objective of this study is to determine the levels of heavy metal contents in sachet water produced in Damaturu, the Yobe state capital. The result is expected to provide information to the consumers on the need to drink only sachet waters which satisfied WHO and NAFDAC requirements to safeguard human health.

2.0 MATERIALS AND METHODS

2.1 Sample Collection

Though quite a number of sachet water manufacturing outfits are available in the area of study but only representative samples which were available at the period of study were considered. Twelve different brands of 500ml sachet water samples were purchased from different vendors in Damaturu, Yobe State capital. Duplicate samples were collected per brand, coded one (1) to twelve (12) and analyzed within 8 hours of sample collection.

2.2 Analysis

The heavy metal concentrations of the water samples were determined using the WAGTECH international physicochemical water analysis kit. The procedures employed in these determinations were as contained in the manufacturer's manuals for the determination of each metal using the designated tablets for the metal of interest.

3.0 RESULTS AND DISCUSSION

The levels of the heavy metal of the sachet drinking water examined in this study are presented in Figs. 3.1 and 3.2.

Fig. 3.1 shows heavy metal concentrations (Cu, Fe and Zn) $\geq$ 0.02mg/l indicated by all the samples while Fig. 3.2 recorded samples with heavy metal

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concentrations ≤ 0.006mg/l. In Fig. 3.2, the entire samples contained different levels of Manganese (Mn), 50% and 60% of the samples contained varying proportions of Chromium (Cr) and Aluminium (Al) respectively.

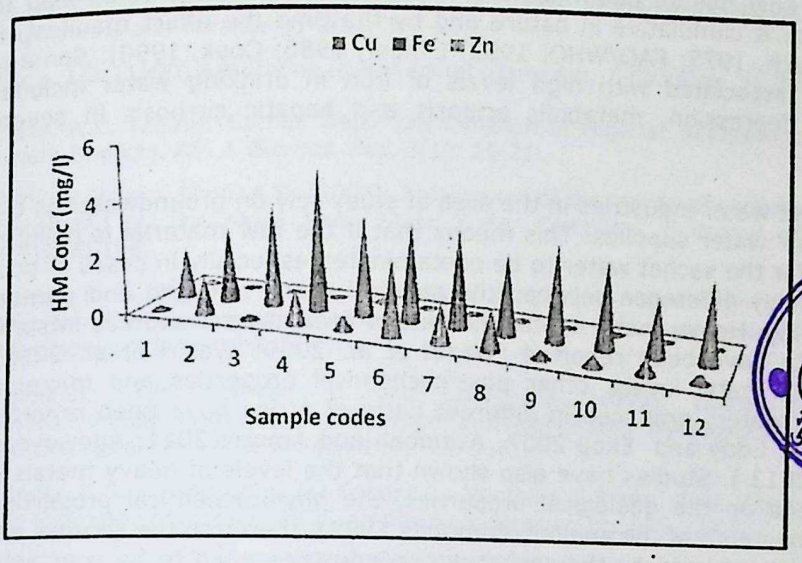

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Fig. 3.1: Heavy metal (HM) concentrations (≥ 0.02mg/l) in the tested sachet water samples

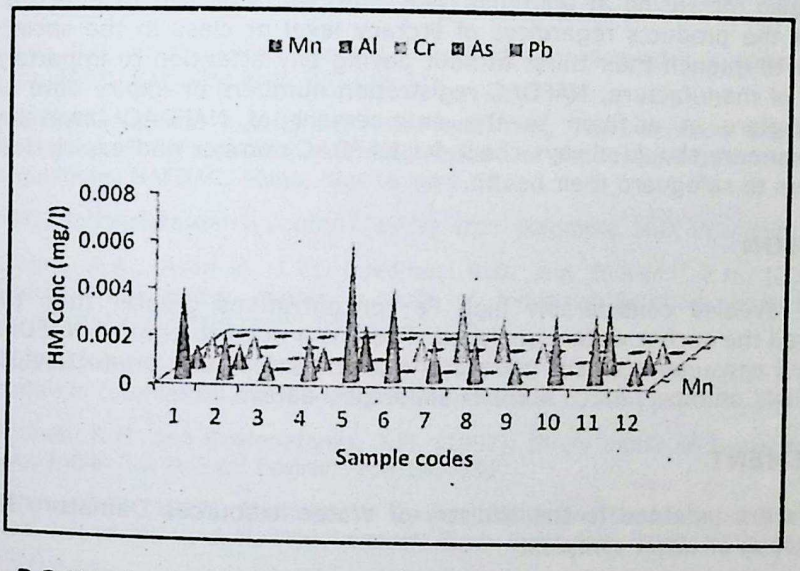

Fig. 3.2: Heavy metal (HM) concentrations (≤ 0.006mg/l) in the tested sachet water samples.

Arsenic (As) (0%) and Lead (Pb) (0%) were tested but not detected and their absence indicate that all the samples were free from the toxic effects of As and Pb.

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However, the concentrations of iron (Fe) (Fig. 3.1) in the entire samples were noticed to be higher than the NAFDAC permissible limit of less than 0.3mg/l. Higher concentrations above 0.3mg/l have been reported in countries various forms of iron salts are used in water treatment and iron pipes are used for water distribution (NRC, 1979). Though iron is needed by the body to satisfy its nutritional requirements, but only minute quantities are required as high doses could lead to metal toxicity which is cumulative in nature and by the time the effect manifest, it may be lethal. (Fisch, 1975; FAO/WHO, 1983; Elinder, 1986; Cook, 1990). Some of the health effects associated with high levels of iron in drinking water includes vomiting, cardiac depression, metabolic acidosis and hepatic cirrhosis in severe cases.

All the sachet water industries in the area of study rely on groundwater as the major source of raw water supplies. This means that if the raw material is polluted there is likelihood for the sachet water to be contaminated especially in cases of poor filtration, and the only difference between the polluted source and the end product will be the packaging. Heavy metal contaminations of groundwater sources in some parts of Yobe state have been reported (Waziri *et al.* 2009; Waziri *et al.* 2012). Variations in heavy metal levels, other physicochemical properties and microbial contents of sachet waters produced in different parts of Africa have been reported (Edema *et al.* 2001; Eddy and Ekop 2007; Asamoah and Amorin 2011; Adewoye *et al.* 2011, Waziri, 2012). Studies have also shown that the levels of heavy metals in groundwater depend on the geological properties, the physicochemical properties, the porosity and the depth of the aquifer (Edmunds 1999), therefore the sources and processing of raw water used by the sachet water industries need to be constantly monitored.

The popularity of sachet water is increasing and establishment of new sachet water factories is also increasing at alarming rate. However, it is sad to note that most consumers of the products regardless of literacy level or class in the society consume the water to quench their thirst without paying any attention to important features like place of manufacture, NAFDAC registration numbers or expiry date on the products. Therefore in addition to the enforcement of NAFDAC laws and guidelines, the consumers should always check for NAFDAC number and expiry date on the sachet waters to safeguard their health.

4.0 CONCLUSION

This study revealed considerably high Fe concentrations greater than the tolerable limits, in all the sachet waters analyzed. There is a need to enforce NAFDAC regulatory laws and consumers should always check and reject any product which does not have NAFDAC number, batch number and expiry dates.

ACKNOWLEDGEMENT

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THEORETICAL MODEL OF IONOSPHERE OF VENUS BASED ON VENUS EXPRESS (SVEDHEM *et al.* 2009)

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ABSTRACT

VIRTIS-MIR,VERA SPICAV and ASPERA-4 measurements on Venus Express provide a valuable data for a systematic studies of Ionosphere of Venus. The present paper focuses on the development of a new theorical model of the ionosophere of Venus based on the new data of neutral species, temperature profile, magnetic pressure etecetra. The result obtained are found to be in good agreement with the results obtained in Venus Express Mission.

Key words: Solar wind Interaction, Ambipolar and eddy diffusion coefficients, transition height.

INTRODUCTION

The one dimensional continuity equation is given by

$$dn_i/dt\ P_i - n_iL_i - d\phi/dz \quad \text{.....(i)}$$

Where n_i is the number density, P_i is volume production rate, L_i is loss frequency and ϕ is the vertical diffusion term.

The steady state solution leads to

$$0 = P_i - n_iL_i - d\phi/dz \quad \text{.....(ii)}$$

For photochemical equilibirium $d\phi/dz = 0$ and ion density is given by

$$n_i = P_i/L_i$$

To account for diffusion, we use the momentum equation

$$\phi = - n_i/n_em_i\upsilon_{in}\ [\ dP_t/dt + n_em_i\ g] \quad \text{.....(iii)}$$

Where υ_{in} is the ion-neutral momentum transfer collision frequency, n_e is the electron number density and P_t be total pressure and is given by

$$P_t = n_ekT_e + n_iT_i + B^2/2\mu_0 \quad \text{.....(iv)}$$

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Where T_i and T_e be the ion and electron temperatures respectively. μ_0 is free space permeability. The last term $(B^2/2\mu_0)$ is magnetic pressure which is included to account solar wind pressure and B is the magnetic field.

Diffusion is finally calculated by modified equation (including thermal diffusion also) and is given by

$$\phi = - D [dn_i/dz + n_i/n_e . T_e/T_i + dn_e/dz + n_i/T_i \; d(T_e + T_i)/dz + n_i/H_i + n_i\alpha /T_i . dT_i /dz + n_i/(n_e kT_i) \; d/dz \; (B^2/2\mu_0)] \quad .....(v)$$

Where $D = n_i kT_i /m_i \upsilon_{in}$ = Ambipolar diffusion coefficient

$H = kT_i /m_i g$ = Scale height.

The general equation used in our model is given by

$$dn/dz = - [\phi/(D + K) + n_i/(D + K) [D /H_i + K/H_{ave}] + n_i/n_e . T_e/T_i . dn_e/dz +$$

$$n_i/T_i . d(T_i + T_e)/dz + n_i/(n_e kT_i). d/dz \; (B^2/2\mu_0) + n_i\alpha_i /T_i \; dT_i/dz \quad .....(vi)$$

We include thermal diffusion and eddy diffusion. K is eddy diffusion coefficient.

and $$d\phi/dz = P_i - n_i L_i \quad .....(vii)$$

The set of equation given above was solved simultaneously by using iteration method. Approximate initial values of nearly the same order were presumed for given iteration. Arithmatic mean of the initial value and calculated value for each unknown constituent were taken as initial input values for the second iterations were done by taking arithmeic mean of the input and calculated output values as initial values for next cycle. After each cycle the condition for electroneutrality was tested and the process was repeated until it was achieved within an accuracy of one percent. The whole process was repeated at each height at an interval of one kilometer using the value of chemical coefficient which were calculated corresponding to the particular temperature of the level. A number of ions have been left out because they are always unimportant and never reach abundance of 10^{-3} cm^{-3}. Among the ions considered are all of the major ions of each region of the ionosphere as well as all of the significant minor ions and a few others which are included in

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order to show their significance. In this section we will discuss the overall flow of ionization through charge transfer reactions, justify the omission of certain species and finally particularize our discussion to those reactions which dominate in regions of peak ionization.

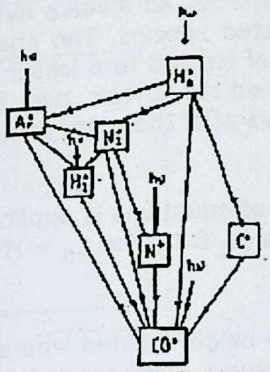
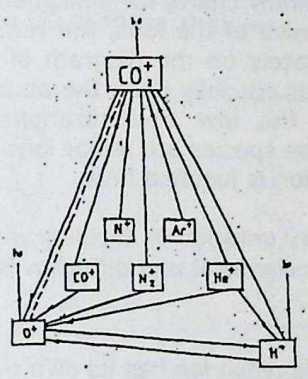


FIG – 1



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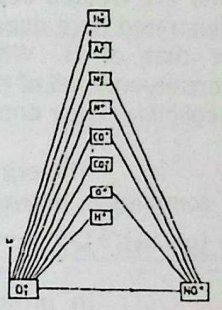

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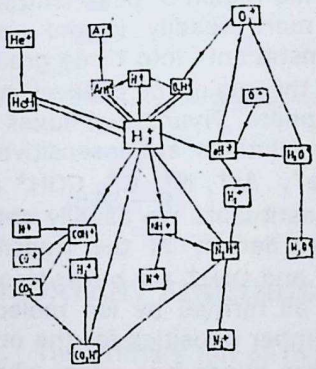

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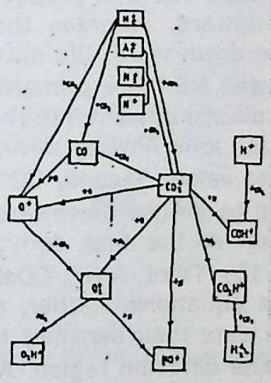

FIG – 5

The overall charge transfer process is illustrated in the series of diagram shown in figure 1 to 5. In these diagrams we do not take account of the relative important of certain reactions channels, but rather include most of the possible ions and show which other ions can create them through charge exchange reactions with one or more of the neutral species present. Each diagram also includes an idication of which ions are created by the direct action of sunlight on the atmosphere.

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As in virtually all ionospheric situations studied to date the ionization is transferred to the species of lowest ionization potential that can be made with the available atoms and molecules. The atomic ions, which are slow to recombine, transfer their charge to molecular ions which are lost more readily. All of these features are illustrated in the first three diagrams (Fig. 1 to Fig 3). These can be thought of an illustrating the highly energetic ions, the medium energy ions and the low energy ions respectively.

These three flow charts for ionization describe the processes involved in the production of twelve of the ions, the remaining species all involve hydrogen and are treated separately on the diagram of protonated species. The chemistry illustrated here depends crucially upon the abundance of H_2 and to a lesser extent of that of H. With the low concentrations assigned to these two neutral constituents, all of these species are minor ions and several of them are completely negligible. Their omission is justified here.

The primary criterion in deciding which set of equations is applicable in a comparison between chemical and diffusion life times (t_C & t_D) [as $t_D = H^2/D$, $t_C = (\alpha_{ix} n_x)^{-1}$].

In principle, each ion has its own transition height located where these two life times are equal. The general trend is for the heavy, low energy molecular ions, such as CO_2^+, O_2^+ and NO^+ to begin to diffuse at lower altitude than atomic ions like O^+, C^+ and N^+. We have chosen the transition height as a rough average of the separate heights of the various constituents.

In physical situations where diffusion is dominant, the direction of flow is from source to sink. The ions produced primarily in the region of peak ionization tend to diffuse upward, whereas those produced more readily in the upper ionosphere diffuse down ward. We divide our ionic constituents into three groups. First CO_2^+, O_2^+ and NO^+ are primarily produced in the region of peak electron density and they diffuse upward into the topside ionosphere. Their initial fluxes are less than those for ions flowing downward and the solutions are insensitive to changes in starting value. Second, CO^+, N_2^+, O^+, He^+, Ar^+, N^+, C^+, COH^+ and OH^+ are all found to diffuse downward. For these constituents we usually obtain continuity equation in the first derivative of number density at the transition altitude to within 1%. Third, ArH^+, CO_2H^+, N_2H^+, NH^+ and O_2H^+ are never treated with the diffusion equations. Rather, since they are all formed by ion molecule reactions, we calculate their densities by using the number densities for the other ions obtained in the diffusion region. ArH^+ and NH^+ are minor ions every where. O_2H^+, CO_2H^+ and N_2H^+ are only important in the region at and below the peak. We have calculated electron density, ion density for several major and minor ions, calculated electron density is shown in fig. 6. We have defined a major ion to be one which accounts for 1% of the electron density at same height. We include all the major ions in figure 7. The next two figures 8 and figure 9 show progressively less important species. We found that no hydrogen containing ions are of major importance in our model region. The peak is chiefly O_2^+ with some CO_2^+ presence. NO^+ is significant at low altitudes. Photo ionization of neutral species CO, CO_2, O, O_2, H, H_2, N, N_2, He, Ar has been calculated. Figure 10 shows the direct photo production rates. The fact that the lower tip in peak ionization is due to more energetic, deeply penetrating radiation is shown by the behaviour of these

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profiles. in this region. The irregularities at about 250 km in the O_2^+, NO^+ and CO_2^+ curves are due to transition between photochemical and diffusion equations. The upward diffusion of O_2^+ is included and this leads to O_2^+ remaining a significant ion at quite large altitudes. He^+ is not the dominant topside ion. This is a direct consequence of taking into account the dissociation of CO_2 in a reasonable quantitative manner. Without assuming any C in our neutral atmosphere or the direct photo production of C^+, We still get large topside density of C^+. This is due to the large abundances of He^+ and CO at these altitudes.

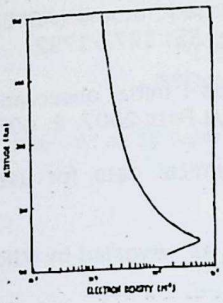


FIG – 6

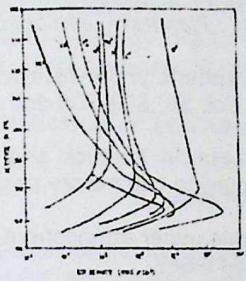


FIG – 7

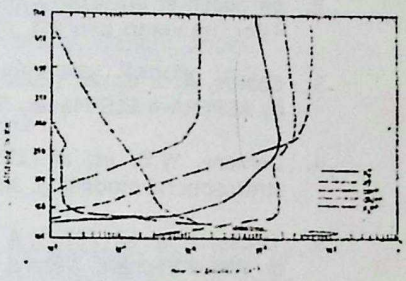
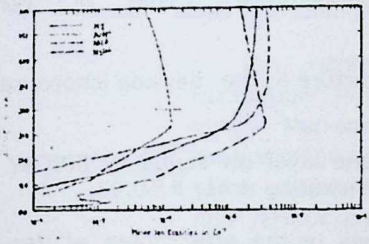


FIG - 8



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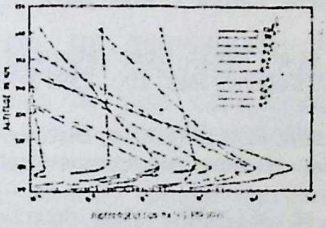

FIG – 10

IMPORTANT FINDINGS ARE

1. The primary ion of the Venus ionosphere in the region from 200 km to 500 km is O^+. O_2^+ is second major ion in the same region.
2. H_2 is substantially dissociated in the Venus ionosphere and is of little importance.
3. The neutral models of together with our ionospheric model give the best explanation to the date of the primary ionospheric peak.
4. Comparison between our models and the Venus Express results for the region below the peak indicate that the high energy solar fluxes we used are larger than those actually present at the time of this encounter.
5. We feel that although a very close picture of the ionospher may be forecasted on theoretical grounds, the exact picture is very difficult to forecast because the reaction rates and other constants used have been calculated in the laboratory where the external conditions may be quite different from that

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existing in the ionosphere. We have tried to realise the real situation by considering the solar wind effect and retrogate motion of the planet and therefore claim to have approached almost realistic situation. The results obtained by us are decidedly an improvement over the previous works in this regard.

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IMPACT OF MINING ON GEOHYDROLOGICAL SETUP: A CASE STUDY OF RANIGANJ COALFIELD, DISTRICT-BURDWAN, WEST BENGAL, INDIA

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ABSTRACT

Recent expansion of mining activity in the Raniganj Coal-Field of Burdwan district has caused major fluctuations of ground-water level. The impact of mining operations has not only lowered the water quality, but has also resulted in fall of the ground-water table. As a result, wells, and ponds have been dried up in surrounding villages of the region, as well as, the river morphology has also changed at various places.

The rainfall pattern has not revealed any significant fluctuations in the Raniganj Coal-Belt during the last twenty-five years. Man-made factors such as rapid industrialization and deforestation are aggravating the situation with regard to ground-water availability. The surface of the region is undulating where we find various parts of it were formerly covered with forests and cultivated land. Such a surface encourages surface-runoff and little groundwater recharge. This paper tries to focus on the impact of mining on the groundwater regime and the resultant imbalance of the ecosystem of the area.

Keywords : Anthropogenic activity, Aggravating , Abandoned mines ,Disrupted drainage ,Hydrological set up, Topographic gradient, Quarry depressions.

1.INTRODUCTION

1.1 The Study Area: The major part of the Raniganj coal-field is located in the western part of the Burdwan district, West Bengal, and comprises of an area of nearly 2,000 square kilometers. The latitudinal and longitudinal extents of this area is 23°33′ to 23°53′ North and 86°37′ to 87°23′ East respectively. Besides this, small parts of Raniganj coal-field occurs at Damodar in Bankura, across the Ajoy river in Birbhum district of West Bengal; and also across the Barakar in Dhanbad district of Jharkhand.

The Eastern Coalfields Limited (ECL) has divided this part of Raniganj coalbelt into thirteen areas, namely Pandaveswar, Bankola, Kunustoria, Kenda, Sodepur, Sitarampur, Slalanpur, Kottadih, Jhanjhra, Kajora, Satgram, Sonepur and Sripur.

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The Administrative units are eleven Police Stations, namely Barabani, Salanpur, Kulti, Hirapur, Raniganj, Asansol North and Asansol South, Jamuria, Ondal, Pandaveswar and Faridpur all are located in the western part of Burdwan district.

OBJECTIVE OF THE STUDY

Exploitation of the coal from open cast and underground mines grossly affects the environmental attributes of the region. The effect of mining in any region invariably results in degradation of land as the loss of top soil, forest cover, agricultural land, and changes of hydro-geomorphological conditions ultimately affecting the groundwater level.

The purpose of our present investigation is to assess the impact of mining activities on the groundwater regime through a study of the fluctuations of the water table. The study is mainly confined to the hydro-geological setup of the area, seasonal behavior of the water table during pre- and post-monsoon periods, and the impact on the groundwater of the withdrawal and seepage of water due to subsidence in mines.

METHODOLOGY

In this study the data and information have been collected from various government publications, memoirs and records mainly from the office of the State Investigation Department (SWID), Burdwan, Central Mines Planning and Design Institute Limited (CMPDI); Geological Survey of India; and useful contribution by the predecessors in this field.

Most of the observations in this study are based upon extensive fieldwork in the region. The study is based upon available secondary data and empirical observations which include subsidence of the land, land degradation, changes of water-table leading to a crisis of water at various places. As a consequence of water-level changes, the socio-economic conditions of this area have been changed radically, agriculture has deteriorated, jobs in the rural sector have decreased, and day-to-day living has become even more difficult for local peasant communities, particularly of their women.

In such a work the help of modern equipment to gather data and information relating to pre-field and post-field conditions is essential. However, in their absence, we took the help of water-table data from SWID. We also took the help of toposheets and other available maps. Besides fieldwork, various statistical techniques related to the measurement of hydrological fluctuations were adopted. Such studies on various statistical techniques proved to be meaningful for the purpose of identifying the changes of water level (Lahiri,1985).

DATA SOURCES

Both primary and secondary data have been collected. The primary data were, in the form of unpublished reports and information gathered from the office of Senior Geologist (SWID, Burdwan), ECL, CMPDI etc. along with Field-study by the author.

The secondary data were in the form of census reports as well as on various aspects of coal mining and urbanization in the district.

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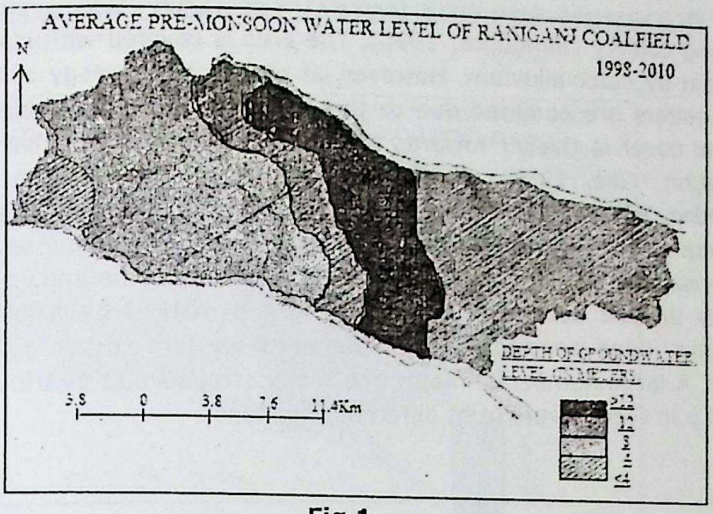

Fig.1

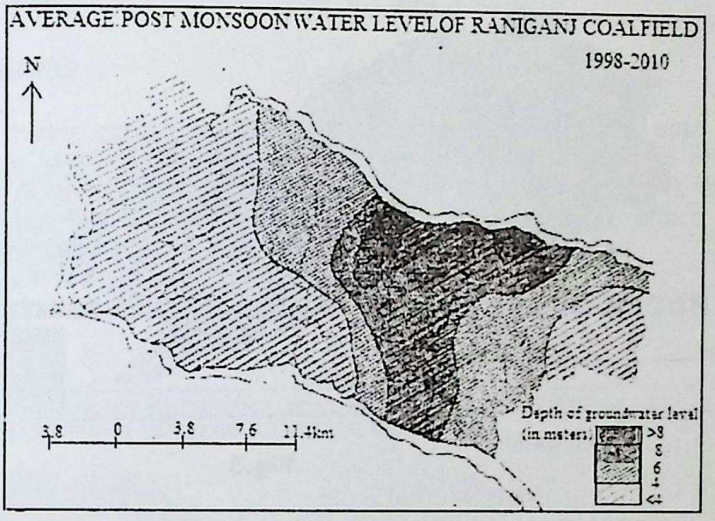

Fig.2

TIME SPAN

The time span chosen for the present study refers to the year 1996 to 2010, though we have frequently referred to the past while discussing the present. Specific attention has been paid on the last twenty-six years, during which the Indian Coal Mining Industry has come into existence as a nationalized public sector activity. This brings us directly to the basic question, "What should be the role of the welfare state in environmental mailers?"

PHYSICAL CHARACTERISTICS OF RANIGANJ COAL-FIELD BELT

The area is characterized by a very gently undulating profile with average height of the ground level varying between 70 to 160 meters. The agricultural landscape has become derelict due to abandoned quarry depressions, large heaps of ash and soils, overburden dumps and the usual characteristic components of a

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working colliery (Sengupta, 1990). The area is covered with clay and in some parts overlain by older alluvium. However, at places, the geology of the region is so that the aquifers are confined due to the presence of impermeable igneous rocks. The alluvial cover is thicker towards the eastern part of the region over the Gondwana formation (Gee, 1932). There are major rivers that flow in this region like the Damodar, Ajoy, and the Barakar. The interfluves of the two main rivers, Ajoy and Kamodar that flow from west to east along the northern and southern boundaries of this area reveal a disrupted drainage system due to the impact of mining. The area that is divided between these two rivers is marked by a low NSN-ESE trending Salanpur Ridge passing through the north-western corner of this area (Blanford, 1861). A large number of major and minor streams and its tributaries (locally called Jhors) join these rivers from different directions.

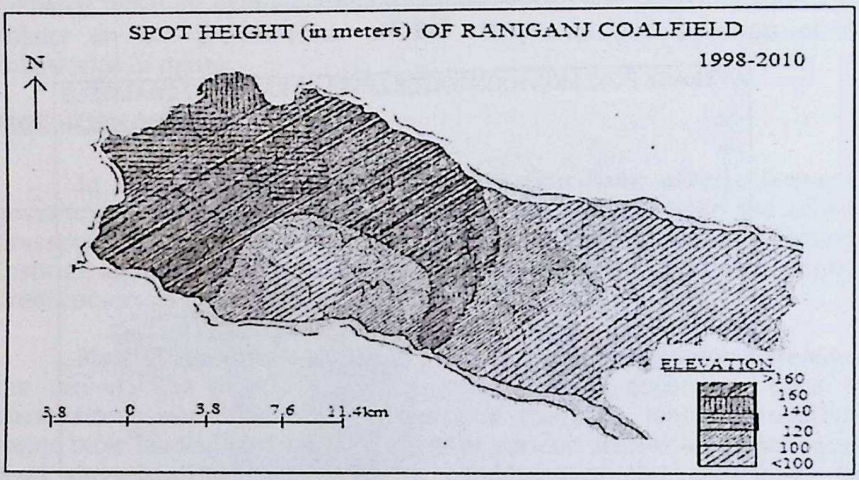

Fig.3

The climatic data indicate a hot tropical condition bordering on the continent with summer temperature rising to 48°C and winter temperature falling to 10°C. And monthly total rainfall varies between 3mm in the winter to 350mm during monsoons.

The water of the principal streams and their tributaries are mostly unsuitable for drinking, bathing, agricultural activity, and any other human use, due to the presence of suspended solids, oil and grease except during the monsoon season. The Damodar, which traverses through all the major -coalfields in Jharkhand before entering WestBengal to mark the southern boundary of the region, that acts as a disposal outlet for the effluents of various collieries and industries and sewage of the burgeoning Urban Centers along its Northern bank and hence is extremely polluted (Sachdev, 1995). The Nunia, a tributary of Damodar, contains deep-blue coloured chemical saturated water for about 10Km downstream from the Blue Factory near Dhadhka, Asansol.

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CORRESPONENCE BETWEEN LOCAL ELEVATION AND PRE-MONSOON WATER LEVEL

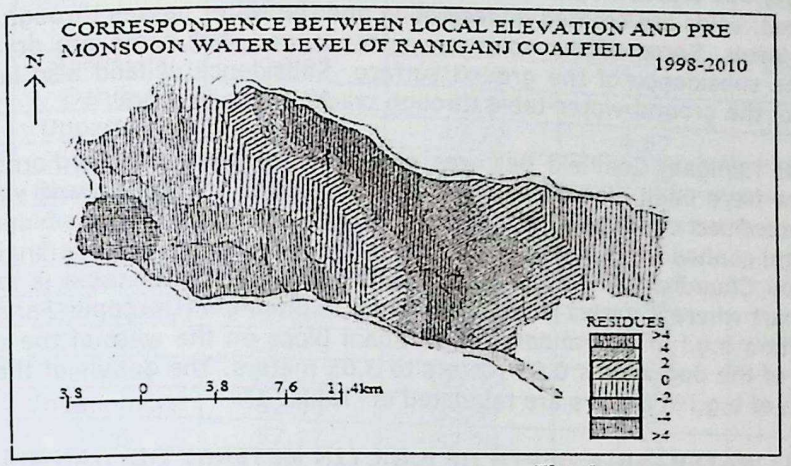

Fig.4

OTHER WATER SOURCES

There are other water resources like dug-wells reaching normally upto a depth of 5.45 meters to 28.00 meters below ground level (b.g.l). There are also other surface water sources, like Tanks, Ponds etc. Most of them have become dry and unsuitable for bathing, fish-culture, and other purposes due to the effect of industrial-water and mine-water (Singh, 1995).

CORRESPONENCE BETWEEN LOCAL ELEVATION AND PRE-MONSOON WATER LEVEL

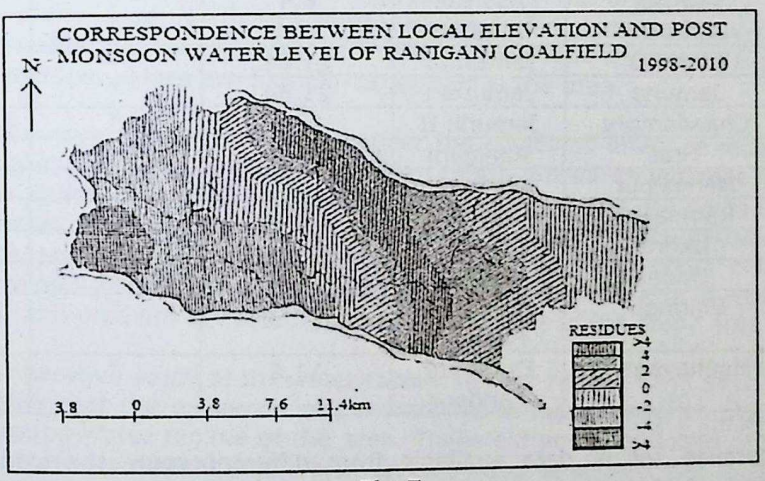

Fig.5

FLUCTUATION OF WATER TABLE

Various factors are generally responsible for the spatial variation of water-table. They include surface Relief, Lithology, Rainfall, Hydrological characteristics and

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Anthropogenic activities (Jana & Dutta, 1996). In the Raniganj Coalfield Belt, water-table at various locations get lowered due to the water release from mines. As the coal is lifted, voids are created underground and the water passes through the cracks to lower levels. Some of the voids are water-logged, but some are dry and often suffers the subsidence of the ground surface. Subsidence of land also leads to the lowering of the ground-water-table through cracks in the bedrock.

The Raniganj Coalfield Belt was previously covered with Sal Forest, most of which now have been cleared out due to expansion of mines. Ground water occurs under unconfined conditions in the topmost weathered mantle and older alluvium, and in semi confined conditions in the Joints, Fractures and other openings in deeper zones (Roy Choudhary & Roy, 1989). The depth of the water table is lower in the western part where it varies from 5.45 meters in Bhiringhi (Durgapur-Faridpur Block) to 28 meters b.g.l in Bhurandargi at Barabani Block on the west of the region. The diameter of the dug-well is 0.95 meters to 3.05 meters. The details of the dug-wells and depth of b.g.l in meters are tabulated in "Table: 1".

TABLE- 1: WATERTABLE DEPTH OF B.G.L (IN METERS) THE RANIGANJ COALBELT.

Well no.	Location	Block	Total depth in Meter.(BGL)	Type of well	Diameter in meters
1	Sanktoria	Kulti	20	Dug well	2.5
2	Dendua	Salanpur	10.78	"	1.9
3	Upperkesia	Salanpur	8.62	"	1.56
4	Sarsatali	Barabani	18.16	"	1.82
5	Bhuradanga	Barabani	28	"	1.8
6	Banagram Rangapara	Hirapur	6.7	"	1.35
7	Asansol	Asansol	8.4	"	1.8
8	Barabani	Barabani	17.6	"	0.97
9	Churulia	Jamuria I	21.84	"	1.8
10	Jamuria	Jamuria I	21.84	"	0.95
11	Chandamore	Jamuria II	15.5	"	2.1
12	Tirat	Raniganj	8.42	"	1.87
13	Mangalpur	Raniganj	12	"	1.87
14	Ramnagar	Ondal	14.06	"	1.8
15	Ukhra	Ondal	15.2	"	3.05
16	Ondal	Ondal	12.07	"	1.87
17	Bhiringhi	Durgapur Faridpur	5.45	"	0.99
18	Madhayaganj	Durgapur Faridpur	11.6	"	1.93

A detailed set of data available from different sources provide a better understanding of the changes in water level from year to year. The water-table isopleths maps have been drawn on the basis of this data during pre- and post-monsoon periods of the study area. Such a method has been tried before (Lahiri, 1985). The average values have been calculated (given in "Table: 2") and are presented in "Fig. 1" & "Fig. 2". They show that the distribution of groundwater following the topographic gradient.

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TABLE- 2 : DEPTH OF GROUND WATER LEVEL (IN METER) AVERAGE VALUES OF PRE- & POST MONSOON REGIME (1998-2010) THE RANIGANJ COALBELT.

Well No.	Location	Pre-Monsoon	Post-Monsoon	Average Pre-Monsoon	Average Post-Monsoon
1	Sanktoria	28.87	19.98	3.61	2.5
2	Dendua	80.54	42.8	5.75	3.06
3	Upperkesia	63.35	43.72	4.67	3.12
4	Sarsatali	145.4	70.61	12.12	5.04
5	Bhuradanga	100.03	51.69	7.15	3.69
6	Banagram Rangapara	76.12	45.89	5.86	3.28 Cont.
7	Asansol	93.12	42.82	6.65	3.06
8	Barabani	89.36	59.03	6.38	4.22
9	Churulia	114.61	57.54	12.73	4.11
10	Jamuria	172.23	122.84	12.31	8.77
11	Chandamore	92.91	35.89	6.64	2.56
12	Tirat	57.17	32.24	6.35	3.58
13	Mangalpur	174.7	104.65	14.56	7.48
14	Ramnagar	86.81	65.74	9.87	8.22
15	Ukhra	162.43	58.99	11.6	4.21
16	Ondal	143.5	67.71	11.04	4.84
17	Bhiringhi	61.47	35.24	4.39	2.52
18	Madhayaganj	100.31	38.8	9.12	2.98

"Fig. 1" represents the average pre-monsoon water level (1998-2010). This isopleths are drawn at 4 meter interval. This figure reveals some interesting features. The depth is less in the south-western part of the Kulti Block in Sanktoria area which indicates the closeness of water to the surface in pre-monsoon time in this area. Depth is greater in the Central portions of the area mainly in north-western part of Barabani, North and south-eastern part of Jamuria Block-I, western part of Jamuria Block-II and eastern part of Raniganj Block and western portion of Ondal Block, medium values are found in other part of the area.

The water level tends to fluctuate under the combined effect of recharge and discharge of the groundwater (Jana & Dutta, 1996). Based on average values in post-monsoon period, a map has been ("Fig.2") where isopleths are being spaced at 2 meters interval. The greatest depths are found at Jamuria Block and also in the north western portions of Faridpur Block. Here the depth is great and though considerable rainfall occurs during monsoon seson. The depth is less in western and southern part, and medium in eastern and middle portions of the study area.

The comparative study of the water-table maps for the pre- and post-monsoon periods indicates that the existence of old workings in many collieries plays a vital role on the ground-water regime of the area. These old and abandoned mines have created underground voids through which ground-water is sucked into lower levels. Subsidence of the land due to either planned mining or due to the presence of such voids also interferes with the ground -water-table and causes fluctuations in the levels. Moreover, there is tendency of drain, the water of the nala(local stream) towards the mine in pre-monsoon period. There is Raniganj coalbelt an increment of about 8 meters of ground-water level from pre- to post-monsoon period, whereas

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the average level of the district is 5 meter, indicating a lesser fluctuation in spite of large scale withdrawal of ground-water through deep tube-wells (Lahiri, 1985).

"Fig.3" shows spot heights or local elevations of these very locations which lead us to a better understanding of ground-water level and also how it is dependent upon local elevations. Ground-water level residual maps which have been drawn for both pre- and post-monsoon periods show the correspondence between these two variables, local elevation and ground-water level.

For pre-monsoon period "Fig.4" isopleths are drawn at an interval of 2. The zone of maximum correspondence (2 to -2) are found in Jamuri Block-I, the eastern part of Barabani, western part of Jamuria Block-II, and in the middle portions of Raniganj Block. The areas under residual value of 4 to 2, -2 to 4 show medium correspondence, and less than -4 values are found in the southern part of the Kulti Block, mainly Sanktoria, where the water-table is closer to the surface due to the nearness of the Damodar.

For post-monsoon periods, the "Fig.5" is drawn at an interval of 2, where the maximum concentration is found in western half and eastern part, medium in eastern part and highest is found in Jamuria, morth of Cinema more. These facts indicate that in this season the water-table is deepest from the surface. The "Table 3" and "Table 4" give clearly the correspondence of these variables.

TABLE - 3 : ESTIMATED & RESIDUAL VALUES OF GROUND-WATER-LEVEL IN THE RANIGANJ COALFIELD BELT.

SL. NO.	SPOT HT. X (m.)	AVG. PRE. Y (m.)	XY	X2	Y2	YC	RESIDUAL Y-YC
1	140	3.61	505.4	19.600	13:03	7.85	-4.24
2	143.21	5.75	823.43	20.507.67	33.06	7.77	-2.02
3	168.64	4.67	787.439.45	28.439.45	21.81	7.12	-2.46
4	135.9	12.12	1647.05	18467.45	146.89	7.94	4.17
5	150.8	7.15	1072.29	22522.5	51.05	7.59	-0.45
6	138.38	5.86	180.91	19149.02	34.34	7.87	-2.03
7	94.62	6.65	629.22	8952.94	44.22	8.99	-2.35
8	134.35	6.38	858.27	18096.98	14.7	7.98	-1.6
9	139.36	12.73	1774.05	18421.21	162.05	7.86	4.87
10	129.54	12.31	1594.64	16780.61	151.54	8.11	4.2
11	140.03	6.64	929.8	19608.4	44.09	7.85	-1.29
12	82.23	6.35	522.16	6761.72	40.32	9.24	-2.9
13	101.23	14.56	1473.91	10247.51	211.99	8.82	5.74
14	94.15	9.87	929.21	8836.28	97.42	8.99	0.87
15	108.48	11.6	1258.31	11766.83	134.56	8.64	2.96
16	82.66	11.04	912.57	6823.68	121.88	9.28	1.74
17	80.25	4.39	352.74	6456.12	19.27	9.34	-4.95
18	78.32	9.12	714.28	6134.02	83.17	9.39	-0.27

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TABLE- 4 : ESTIMATED & RESIDUAL VALUES OF GROUND-WATER-LEVEL FOR POST-MONSOON PERIOD IN THE RANIGANJ COALFIELD BELT.

SL. NO.	SPOT HT. X (m.)	AVG. POST Y (m.)	YC=(A+BX)	RESIDUAL (Y-YC)
1	140	2.5	4.08	-1.58
2	143.21	3.06	4.04	-0.98
3	168.64	3.12	3.78	-0.67
4	135.9	5.04	4.12	-0.92
5	150.08	3.69	3.97	-0.28
6	138.38	3.28	4.09	-0.81
7	94.62	3.06	4.54	-1.48
8	134.53	4.22	4.13	0.09
9	139.36	4.11	4.08	0.03
10	129.54	8.77	4.18	4.59
11	140.03	2.56	4.08	-1.52
12	82.23	3.58	4.67	-1.09
13	101.23	7.48	4.47	3
14	94.15	8.22	4.54	3.68
15	108.48	4.21	4.4	-0.19
16	82.66	4.84	4.66	0.18
17	80.35	5.52	4.68	-2.16
18	78.32	2.98	4.71	-1.73

"Fig.6" and "Fig.7" give the estimated water-level of the study-area, the maps are drawn by calculating the formula **yc=a+bx** , where **yc**=estimated residual. There are spatial variations of **Actual A-1** estimated ground-water-level in both pre- and post-monsoon season. In pre-monsoon season highest estimation is found in Madhyaganj (9.394m) in Durgapur-Faridpur Block, but the actual value is 9.12 meters. The point to note here is that this area has the lowest water-table. In the Upperkesia area (Salanpur Block) the estimation is lowest (7.127 meters). Whereas the actual value is 4.67m, indicating, the Zone of maximum negative correspondence i.e. the water table is closer to the surface in this area. In post-monsoon regime the picture, however, is different. The highest estimated level is found in Madhyaganj (4.7055m) in Durgapur-Faridpur Block and lowest in Upperkesia (3.785m) in Salanpur Block. This difference may be explained by the intensiveness of mining activity in the respective regions.

In general, the fluctuation of the groundwater level during the inter-monsoon period is high in the northern and south-eastern parts, and low in western parts. The great contrast of water level in these two seasons is due to underground and open cast mining in this region.

The fluctuation in the ground-water-level could be a natural phenomenon, but it is not so evidenced from the fact that over the years, the average depth of groundwater level has been falling in this region. Our data refers to the time period between 1983 and 1995 and the following data in "Table 5" clearly brings out the falling ground-water-table "Fig.8". This is notable for several factors: rapid urbanization in the area and hence increased water demands, expansion of open cast and a mining, greater incidence of planned land subsidence.

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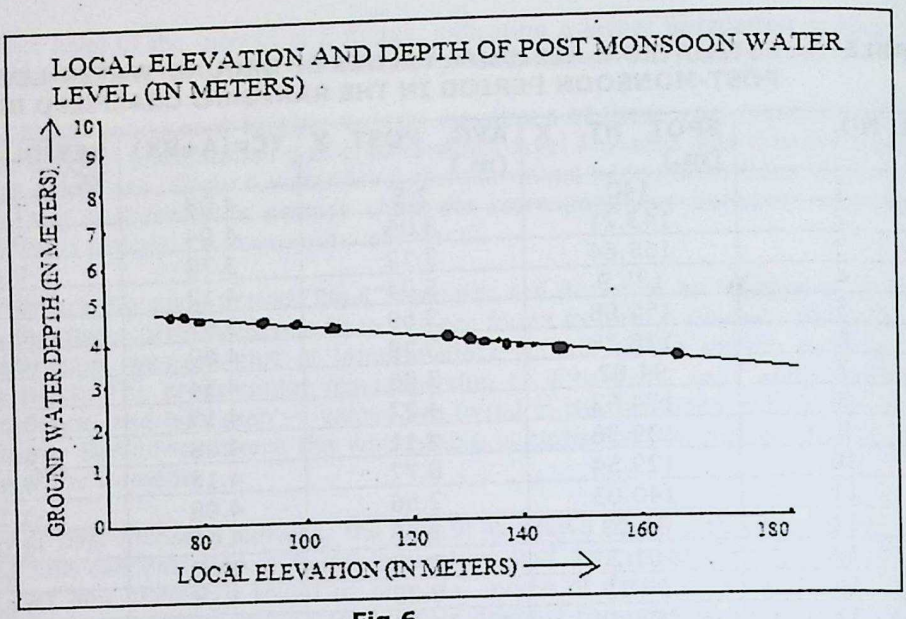

Fig.6

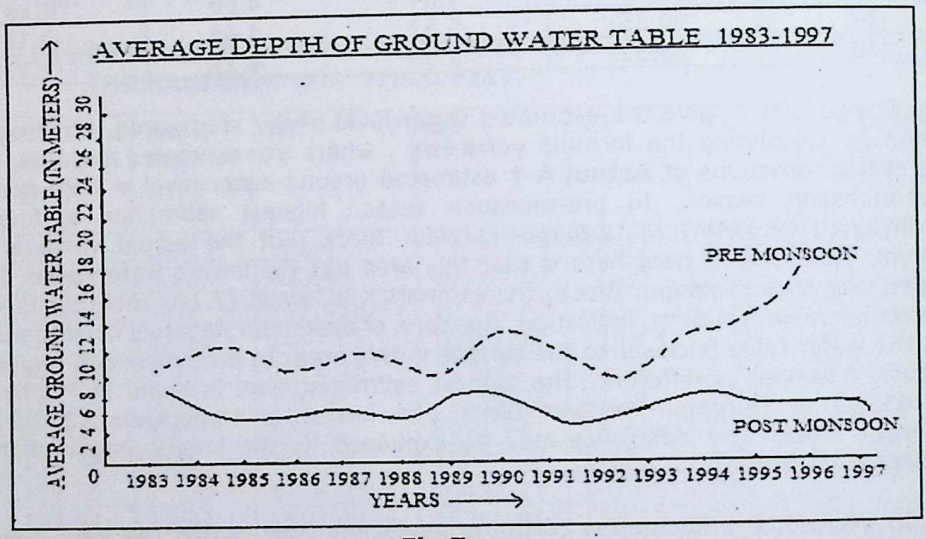

Fig.7

The analytical data indicate that the ground-water is alkaline in nature. Concentration of the chemical constituents is within the permission limits for human consumption, the total hardness of $CaCO_3$ in ppm is 20 to 450 indicate that the nature of water is hard. In general, the ground water is unsuitable for domestic as well as industrial use in many areas of this coalfield.

During our field survey, we noticed that the underground water discharged by the mines was objectionable in respect of colour. We also noticed turbidity and high suspended solids content. The water was also contaminated with bacteria, as majority of the population was affected with water-borne diseases and skin disorders.

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TABLE- 5: AVERAGE DEPTH OF GROUNDWATER (IN Mt) IN RANIGANJ COALBELT.

YEARS	PRE MONSOON	POST MONSOON
1998	9.42	5.52
1999	9.91	4.44
2000	8.76	4.77
2001	9.02	3.85
2002	8.7	4.61
2003	7.1	5.72
2004	7.99	4.66
2005	6.63	3.31
2006	7.93	4.28
2007	6.65	3.99
2008	7.63	3.37
2009	8.3	3.38
2010	11.49	2.89

TABLE- 6: CHEMICAL QUALITY OF GROUND WATER

Water samples have been collected by the office of the Senior Geologist, SWID, Burdwan ranges of different constituents in ground water of the area are as follows (as per SWID data).

SL.NO.	CONTENT	RANGE
1	pH	6.9 to 8.6
2	Spl conductivity in micron/cm at 25°C	56 to 1300
3	Carbonate (CO33) in ppm	0 to 160
4	Bi-carbonate (H3CO3) in ppm	20 to 360
5	Chloride (Cl) in ppm	40 to 220
6	Total hardness as CaCO3 in ppm	20 to 450
7	Iron (Fe) in ppm	0 to 1.43
8	Total dissolved solids (TDS)	36 to 832
9	Depth in meter	5.46 to 43.4

CONCLUSION AND RECOMMENDATION

The Raniganj Coalbelt of Burwan district WestBengal, is underlain by more or less efficient aquifers. The fluctuations of groundwater table varies from one year to another year in both pre- and post-monsoon regimes is a notable fracture of the region. Rapid urban development and population growth experienced by the region during the period, and the frequent incident of subsidence in the region have contributed to the falling ground water table to severe extent. The ground water table has fallen with every passing year, and the subsidence problem has added to it. Mining of coal, both from underground and open cast pits, is clearly responsible for the hydro-geological changes in Raniganj Coalbelt.

The above analysis thus shows that due to mining activities, the groundwater has been affected quantitatively and qualitatively, while most of the sources of the surface-water do not meet the prescribed standard for public water supply, bathing ghats and often even for fish-cultures (ECL, 1988).

Coal will continue to be a dependable and economically available fuel of long-term supply potential in India. With increasing consumption of coal the adverse impacts would become more pronounced, curiously affecting the groundwater table.

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The environment implication of a falling groundwater table is very serious: the entire urban population growth of the region depends on this source, rural ponds have began to dry up, and the incidence: land subsidence has threatened more areas that before.

The question is can mining be ever made into a sustainable development as a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional changes are all in harmony and enhance both current and future potential to meet human needs and aspirations.

Mining projects are now sanctioned by the government only after clearance by the Ministry of environment & Forest. Major thrust was given in the VIII plan on subsidence control in old and abandoned mines of Raniganj. Mining of coal has to be done in a controlled manner and its pollution effects must be minimized. The environment of the region must be restored back to the pre-mining state or improved once the resources have been exhausted cost evaluation of open cast resources underground mining environments and appropriate selection of the preferred one need to be done integrating environmental considerations with techno economics.

Considering the hydro-geological set up on area it is evident that further mining activity may have a worsening effect on the groundwater regime of the area. Based on this study, the final step will be suggesting a course of action:

(1) To minimize the ground-water-seepage to the mine; and
(2) To evolve a strategy of 'best practice' mining in the Raniganj Coalfield Belt.

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PETROLOGY AND GEOCHEMISTRY OF AMPHIBOLITES IN AND AROUND YENKUR VILLAGE, KHAMMAM DISTRICT, ANDHRA PRADESH, INDIA.

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ABSRACT

An area of about 140 sq.km around Yenkur village in Khammam district of Andhra Pradesh, India consisting of diverse metamorphic rocks ranging from amphibolites to granulite facies of metamorphism has been mapped on 2 cms to 1 km scale.

Petrographic work has been carried out for 60 sections of amphibolitic rocks. The anorthite content of plagioclase is An_{35-45} in hornblende schists and An_{39-48} in amphibolites. In amphibolites, almandine garnet is quite abundant.

Six rock samples of hornblende schists, 30 of amphibolites, have been chemically analyzed for major elements and 20 samples of amphibolites for trace elements have been analyzed. Petrochemical calculations including Niggli values and CIPW norms have been carried out. Two co-ordinate and three coordinate diagrams based on these calculations have been constructed to decipher the petrogenesis of amphibolites.

Key words : Petrology and Geochemistry of Yenkur Amphibolites.

INTRODUCTION

The investigated area is located about 64 km to the east of Khammam which is a District Headquarters and an important railway station on the Hyderabad-Madras line. (Fig. No.1).

An area of 140 sq km was mapped during the *summer season of* 2008 on two centimeters to 1 km scale (Toposheet Nos. 65 C/7 and C/8, Survey of India). About 100 rock samples were collected representing the hornblende schists and amphibolites and out of them 60 thin sections were prepared and they have been studied for their mineralogical and textural relationships. Though there are many important rock types available within this small area, only amphibolites have been investigated for this work for want of space and time.

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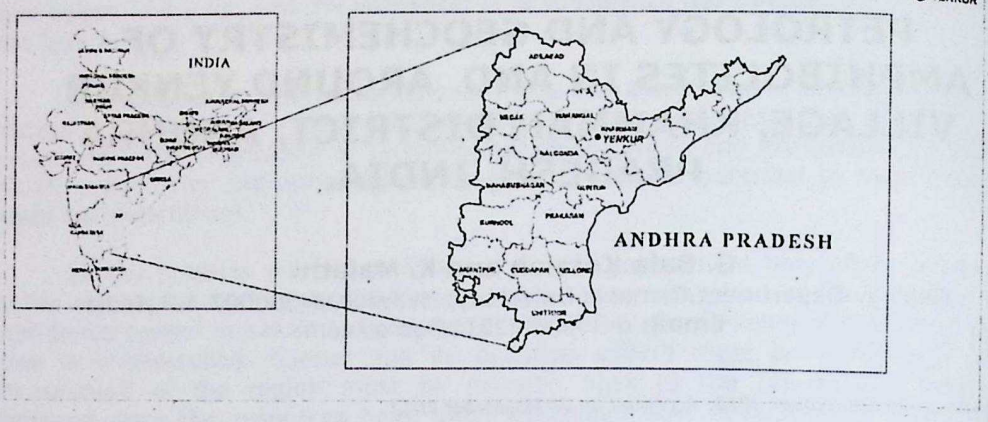
(FIG-1) LOCATION MAP OF STUDY AREA



GEOLOGY

Broadly speaking, the hornblende schists are those rocks in which the hornblende content is more than 70%. Amphibolites are those in which the hornblende content ranges from 70% to 40% and plagioclase shows corresponding increase. Hornblende schists and amphibolites are marked as amphibolites in the geological map (Fig-2).

Amphibolites

In amphibolites (Fig.3) the texture is granoblastic and grain size is of the medium.Megascopically they have hornblendes, plagioclases and garnet. At few places, magnetite, clinozoisite, quartz, scapolites, sphenes were also notices. Sometimes brownish garnets predominate other accessories.Quartz veins are sometimes seen to traverse the amphibolites. Further, large crystals of garnets can be seen in amphibolite outcrops(Fig.4).

PETROGRAPHY

There is a variation in grain size in amphibolites and hornblende schist groups. In general the hornblende schists are finer grained. With increasing content of plagioclase feldspar, recrystallisation also seems to increase and the grain size becomes coarser.

Megascopic Observations

The greenish black hornblende grains, pink garnet, white feldspar and colourless quartz are all clearly identifiable in hand specimens. The texture is fine to medium grained.

In porphyroblastic amphibolites, garnets form the porphyrablasts ranging in size from 2 mm to 3 cms sometimes to 20 cms. They are developed in particular joint planes.

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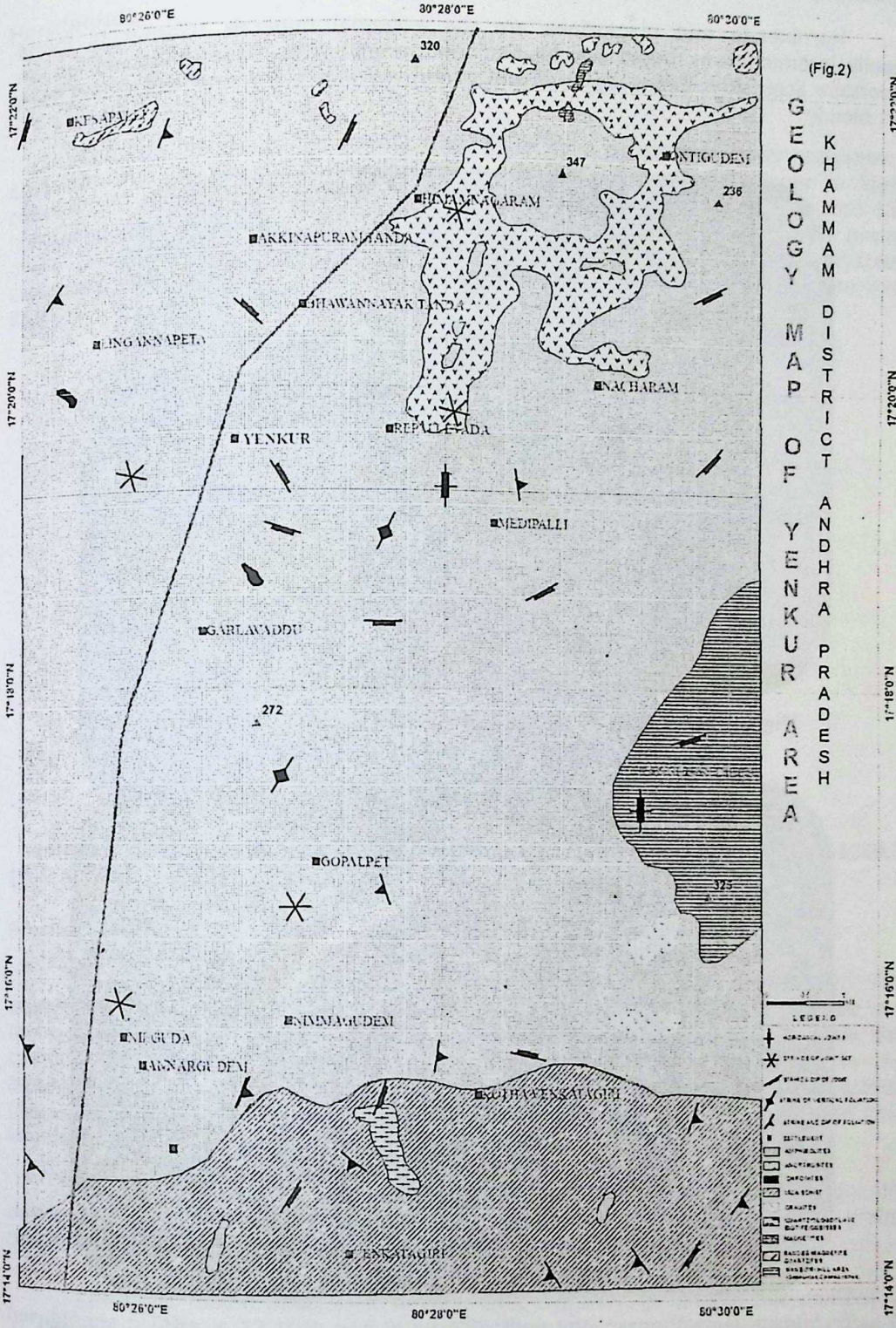

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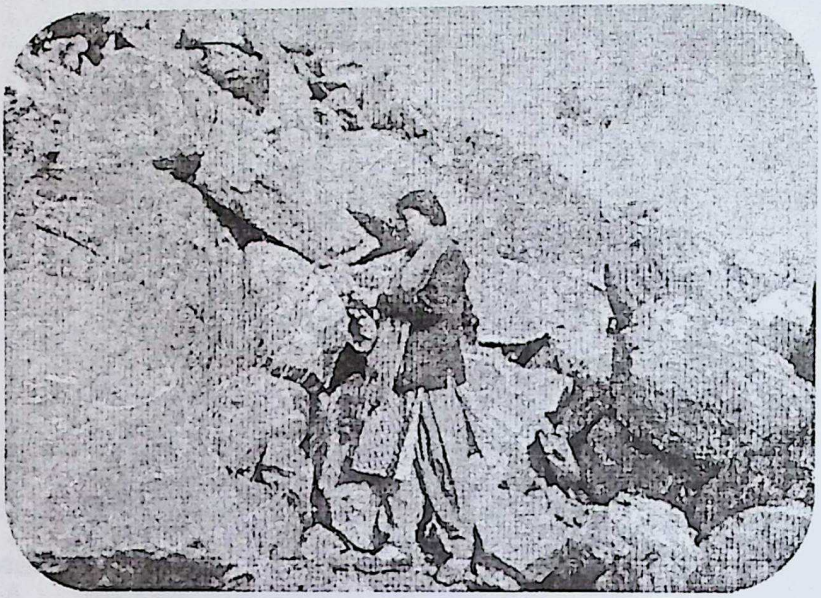
Microscopic Observations

Hornblende and plagioclase are the essential minerals. Garnet is found equally prominent in many samples of the amphibolites. Quartz occurs as an important accessory. Some epidote and clino-pyroxene are found associated with hornblende.



(Fig. 3) AMPHIBOLITE QUARRYING NEAR GOPALPET VILLAGE

FIG.4 : GARNETIFEROUS AMPHIBOLITE WITH FELSIC BAND NEAR AKKINAPURAM TANDA

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Hornblende

It is subidioblastic and medium grained. It is greenish in colour and shows pleochroism: X=Yellowish green, Y = Green and Z = Bluish green, $Z \wedge C = 20^0$: 2 $V = 55^0$ to 70^0, optic sign (-).

The hornblende grains appear (Fig. 5) to have a heterogeneous appearance obviously due to alteration. Sieving by quartz and plagioclase feldspar is fairly common. The contacts between hornblende and plagioclase are ragged, with the hornblende showing a tendency to disintegrate. The outlines of hornblende grains often present concave-convex boundaries with respect to adjacent crystals, especially with plagioclase. The convexity is in general towards the hornblende host itself.

(Fig.5) MICROPOTOGRAPH OF AMPHIBOLITE UNDER CROSSED NICOLS (7.5 X 10)

Plagioclase

The plagioclase shows variations in grain size from 0.1 mm to 0.8 mm. The grains are subidioblastic but some of the grain boundaries along hornblende are highly ragged. Symmetrical extinction angles, in sections normal to 010 show the composition of plagioclase to be varying from An_{39-48}. The plagioclase in the amphibolites of north and towards hill area show higher content of anorthite (An_{45-56}). Twinning in plagioclase is beautifully expressed and the individual twin lamellae are fairly wide.

The commonest twin law is albite law but pericline twins are also frequently noticed. Some of the outlines of plagioclase are hexagonal. The form of such grains much resembles the basal sections of hornblende grains.

From the modal analysis it is clear that the average plagioclase content in hornblende schists is 22.10% and in amphibolites and garnetiferous amphibolites is 31.28%.

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Garnets

The garnets are much variable in size, from those with less than one centimeter ranging upto those large garnets with a diameter of up to 20 cm. They are pinkish brown and reddish brown in colour. The specific gravity of garnet is 3.99. From those properties, it may be concluded that the garnets dominantly are of almandine variety with a little pyrope. The mineral is subidioblastic.

Quartz

Quartz is a common accessory with compositional variations from 1 to 13% in hornblende schists and in amphibolites. Much of it is found as sieve quartz. Apart from this, the grains which occur independently are fairly large. It is xenoblastic. Opaque dust trails and inclusions are rare in quartz grains.

Epidote

Epidote grains seem to be erratic in amphibolites. In some amphibolites they are found up to maximum of 4.41%. The optical properties of epidote are $Z \wedge C = 6^0$, $2V = (-) 86^0$. Hence it is identified as clinozoisite.

Tremolite

In some amphibolites, tremolite and actinolite are also observed as accessories and in some samples they form essential minerals. Tremolite is showing the optical properties of $2V = 86^0$ and optic sign (-) and bluegreen actinolite $2V = 82^0$, optic sign (-) and $Z \wedge C = 15^0$.

Sphene is noticed as a minor accessory in amphibolites and ranges upto maximum of 1.76%. Magnetite is important in some varieties. Apatite is very subordinate. Clinopyroxene is again erratic in its distribution in amphibolites. In some amphibolites it becomes a very important accessory with a percentage of 6. The other minor accessories are orthopyroxene, scapolite and rarely anthophyllite.

GEOCHEMISTRY OF AMPHIBOLITES

Thirty six rock samples of amphibolite samples are chemically analyzed. These include six hornblende schists (Table - 1), thirty amphibolites and garnetiferous amphibolites (Table - 2). The Niggli values and CIPW norms are computed and given in the same tables.

Niggli values of mg against c for the amphibolites (including hornblende schists) are plotted in the diagram (Fig. 6) compiled by Leake (1964). The points of amphibolites follow the trend of Karroo dolerites suggesting the igneous parentage for amphibolites.

This mode of origin is supported by few more diagrams. Niggli mg against k, alk, p, & ti of the studied hornblende schists and amphibolites are plotted in the Figure 7, together with Karoo dolerites which are considered to be the igneous origin (Leake 1964). Some of the plots show erratic in plotting which is because of alkali metasomatism. The plots of si, al, alk, ti and k against fm are shown in the Figure 8, which gives negative trend along with Karoo dolerites indicating igneous origin. In

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the ternary diagram the Niggli values of c-100 mg-(al-alk) are taken and the values are plotted. Again, all the points fall in igneous field (Fig. 9).

Systematic decrease in Niggli mg with increase in alk, si, al and ti is commonly associated with magmatic differentiation in basic magmas. k and alk values are plotted against mg (Fig.10a,10b) for amphibolites but they show erratic variation. This may be due to the alkali metasomatism which is common in amphibolites (Leake, 1964).

TABLE 1 :

Chemical Compositions, CIPW Norms and Niggli values of Hornblende Schists

Chemical Compositions

INDEX	HS 1	HS 2	HS 3	HS 4	HS 5	HS 6	AVERAGES
SiO2	46.19	51.8	46.43	54.6	49.5	48.6	49.5
TiO2	1.84	1.43	1.01	0.8	0.62	1.1	1.1
Al2O3	8.3	12.99	12.9	11.8	11.1	14.82	12.0
Fe2O3	4.5	2.45	3.3	5.3	4.12	5.94	4.3
FeO	9.15	12.82	11.82	10.3	10.6	10.54	10.9
MnO	0.15	0.1	0.3	0.25	0.25	0.2	0.2
MgO	14.29	6.85	6.8	5.9	10.4	6.9	8.5
CaO	8.62	6.75	11.8	7.82	8.82	7.3	8.5
Na2O	3.32	1.9	2.4	1.83	2.8	2.82	2.5
K2O	0.85	0.62	0.82	0.34	0.99	0.82	0.7
P2O5	1.4	0.42	1.4	0.32	0.25	0.35	0.7
TOTAL	**98.6**	**98.13**	**98.98**	**99.26**	**99.45**	**99.39**	

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TABLE 1 (Contd.)

Niggli Vaues (Hornblende schists)

INDEX	HS 1	HS 2	HS 3	HS 4	HS 5	HS 6
Si	91.72	129.54	101.25	140.24	105.27	111.59
Al	9.71	19.14	16.57	17.861	13.91	20.05
Fm	64.47	57.17	49.63	58.5	58.87	54.51
C	18.34	18.08	27.57	21.52	20.09	17.75
Alk	7.46	5.59	6.21	5.11	7.116	7.47
K	0.14	0.17	0.18	0.1	0.18	0.16
Mg	0.65	0.44	0.44	0.4	0.56	0.43
c/fm	2.74	2.69	1.65	1.54	0.99	1.9
Ti	1.77	0.44	1.29	0.34	0.22	0.34
P	0.28	0.31	0.55	0.38	0.34	0.32
Qz	-38.14	7.16	-23.6	19.78	-23.18	-18.32

Robinson and Leake (1975) have developed sedimentary and igneous trends in AFM diagrams. In these diagrams, three corners are taken as Na_2O+K_2O wt% as A, total iron FeO wt% as F and MgO wt% as M. In this ternary diagram (Fig.11), the amphibolites (including hornblende schists) are plotted accordingly. Surprisingly all the points fall towards iron-magnesium rich areas of igneous rocks.

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TABLE 1 (Contd.)

CIPW Norms (Hornblende schists)

OXIDE	HS 1	HS 2	HS 3	HS 4	HS 5	HS 6
QUARTZ	——	5.48	——	9.7	——	——
PLAGIOCLASE	26.87	41.16	42.31	38.46	38.49	49.22
ORTHOCLASE	5.02	3.65	4.85	2.01	5.85	4.85
DIOPSIDE	23.05	4.73	22.93	11.56	22.54	7.19
HYPERSTHENE	——	——	1.79	33.61	3.87	17.04
OLIVINE	32	——	20.41	——	25.46	16.41
ILIMENITE	3.49	2.72	1.92	——	1.18	2.09
MAGNATITE	1.06	1.2	1.19	1.22	1.16	1.28
APATITE	3.24	0.97	3.24	0.74	0.5	0.81
NEPHELINE	3.5	——	——	——	——	——
HEMATITE	——	——	——	1.52	——	——
TOTAL	**98.23**	**59.91**	**98.64**	**98.82**	**99.05**	**98.89**

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TABLE 2

Chemical Compositions, CIPW Norms and Niggli values of Amphibolites

Chemical Compositions

OXIDE	AM 1	AM 2	AM 3	AM 4	AM 5	AM 6	AM 7	AM 8	AM 9	AM 10	AM 11	AM 12	AM 13	AM14	AM15
SiO_2	46.3	50.05	55.15	49.45	51.52	47.5	45.8	50.62	52.52	52.65	52.41	49.31	47.45	52.5	52.13
TiO_2	0.45	1.52	1.01	0.83	0.69	1.35	0.93	1.19	2.93	1.1	0.88	2.13	1.33	0.96	0.38
Al_2O_3	16.01	12.01	14.52	13.05	14.55	13.72	12.5	13.15	15.75	13.22	11.57	16.62	14.44	14.96	11.42
Fe_2O_3	3.99	4.8	3.2	3.7	3.2	3.01	5.05	4.9	2.15	1.52	4.77	4.11	3.14	4.65	4.66
FeO	8.93	8.52	7.3	10.05	8.15	9.75	11.18	6.25	7.64	8.8	9.99	7.29	10.84	8.44	9.89
MnO	0.75	0.36	0.28	0.25	0.29	0.35	0.55	0.05	0.32	0.22	0.19	0.18	0.11	0.11	0.21
MgO	6.5	7.99	8.59	7.3	10.1	8.41	11.5	12.01	8.5	7.15	5.99	6.85	7.77	6.88	6.49
CaO	12.1	10.43	7.26	9.86	7.01	10.35	10.2	7.5	7.75	10.75	9.2	10.09	11.22	6.67	9.86
Na_2O	2.75	2.25	2.01	2.55	2.33	2.98	1.22	1.99	1.65	2.4	1.59	2.33	2.56	1.1	1.59
K_2O	1.01	1.02	0.85	1.01	0.46	0.75	0.29	0.51	0.3	0.38	0.33	0.79	0.66	0.31	0.29
P_2O_5	0.21	0.25	0.24	0.19	0.18	0.26	0.26	0.28	0.21	0.2	0.22	0.16	0.11	0.19	0.22
TOTAL	99.00	99.2	100.41	98.24	98.48	98.43	99.48	98.45	99.72	98.39	97.14	99.86	99.63	96.77	97.14

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TABLE 2 (Contd)

Chemical Compositions

OXIDE	AM 16	AM17	AM18	AM 19	AM 20	AM21	AM22	AM23	AM24	AM25	AM26	AM27	AM28	AM29	AM30	AVER AGE
SiO_2	50.89	48.32	52.38	49.65	52.35	48.12	48.32	52.96	50.89	47.95	49.43	47.54	44.79	45.59	51.29	**49.86**
TiO_2	0.58	1.33	1.04	0.88	1.22	0.56	1.83	2.85	1.69	1.44	1.03	1.83	1.89	1.77	0.89	**1.28**
Al_2O_3	14.17	13.82	13.82	13.82	12.99	14.8	12.82	15.18	14.98	11.89	13.97	13.74	15.11	12.57	15.73	**13.9**
Fe_2O_3	2.61	2.55	1.33	3.94	4.11	2.44	2.77	2.8	4.46	3.91	3.36	3.14	4.34	4.2	4.5	**3.58**
FeO	8.21	10.48	8.55	10.1	9.88	10.1	10.48	7.33	9.5	11.65	9.72	10.84	8.66	11.65	9.8	**9.33**
MnO	0.15	0.26	0.16	0.12	0.13	0.22	0.22	0.23	0.11	0.27	0.11	0.11	0.17	0.25	0.14	**0.23**
MgO	7.16	7.27	6.91	7.44	7.44	7.14	7.27	8.69	4.4	8.99	8.72	7.47	8.13	9.66	7.97	**7.89**
CaO	11.38	10.45	10.54	9.78	6.14	9.89	10.45	7.15	9.38	9.78	9.11	11.32	11.55	9.78	7.69	**9.49**
Na_2O	1.66	2.65	2.32	2.57	1.29	2.57	2.57	1.49	1.14	1.58	2.62	2.56	2.69	1.58	1.22	**2.06**
K_2O	0.31	0.81	0.39	0.91	0.54	0.88	0.58	0.21	0.59	0.94	0.69	0.66	1.12	0.44	0.33	**0.61**
P_2O_5	0.29	0.11	0.14	0.13	0.81	0.11	0.12	0.14	0.3	0.21	0.24	0.1	0.19	0.23	0.2	**0.22**
TOTAL	**97.41**	**98.05**	**97.58**	**99.3**	**96.9**	**96.8**	**97.4**	**99.0**	**97.4**	**98.6**	**99**	**99.3**	**98.6**	**97.7**	**99.76**	

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TABLE 2 (Contd)

Niggili Values (Amphibolites)

INDEX	AM 1	AM 2	AM 3	AM 4	AM 5	AM 6	AM 7	AM 8	AM 9	AM 10	AM 11	AM 12	AM 13	AM 14	AM 15
SI	99.55	113.65	136.57	113.27	119.36	103.72	90.83	112.73	130.23	127.71	132.81	114.88	101.95	137.67	128.23
Al	20.28	16.07	21.18	17.61	19.86	17.65	14.6	17.25	23.01	18.89	17.27	22.81	18.28	23.11	16.55
Fm	44.71	52.12	53.38	51.04	56.82	50.77	61	59.82	51.95	46.93	53.3	45.55	49.64	54.82	53.21
C	27.87	25.37	19.26	24.2	17.4	24.21	21.67	17.89	20.592	27.93	24.97	25.18	25.83	18.74	25.98
Alk	7.11	6.43	6.16	7.13	5.91	7.35	2.71	5.02	4.44	6.23	4.43	6.43	6.23	3.31	4.24
K	0.19	0.23	0.21	0.2	0.11	0.14	0.13	0.14	0.1	0.09	0.12	0.18	0.14	0.15	0.107
Mg	0.46	0.51	0.59	0.48	0.61	0.53	0.55	0.66	0.6	0.55	0.42	0.52	0.5	0.49	0.44
c/fm	0.72	2.59	1.88	1.43	1.2	2.21	1.38	1.99	5.46	2	1.67	3.73	2.15	1.89	0.7
Ti	0.72	0.24	0.25	0.18	0.17	0.24	0.21	0.26	0.22	0.2	0.23	0.15	0.1	0.21	0.22
P	0.62	0.48	0.36	0.47	0.3	0.47	0.35	0.29	-0.39	0.59	0.46	0.55	0.52	0.34	0.48
Qz	-28.9	-12.1	11.9	-15.3	-4.29	-25.7	-20	-7.34	12.5	2.78	15.05	10.86	-22.99	24.41	11.25

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Qz	-28.9	-12.1	11.9	-15.3	-4.29	-25.7	-20	-7.34	12.5	2.78	15.05	10.86	-22.99	24.41	11.25

TABLE 2 (Contd)

Niggili Values (Amphibolites)

OXIDE	AM 16	AM 17	AM18	AM 19	AM 20	AM 21	AM 22	AM 23	AM 24	AM 25	AM 26	AM 27	AM 28	AM 29	AM 30
Si	121.22	109.4	129.26	112.07	136.37	106.37	108.59	132.97	132.97	103.12	111.93	104.84	99.29	96.96	121.56
Al	19.89	18.43	20.09	18.38	19.94	19.27	16.97	22.46	22.95	15.06	18.73	17.85	19.73	15.75	21.97
Fm	46.76	49.22	45.87	51.02	58.76	50.54	51.42	54.34	47.05	57.81	52.5	48.99	45.46	58.1	55.19
C	29.04	25.35	27.86	23.85	17.13	23.42	25.16	19.23	26.13	22.53	22.1	26.75	27.43	22.28	19.52
Alk	4.3	6.98	6.16	6.93	4.15	6.74	6.43	3.96	3.85	4.58	6.74	6.4	7.36	3.85	3.3
K	0.109	0.16	0.1	0.18	0.21	0.18	0.12	0.08	0.28	0.14	0.14	0.14	0.21	0.15	0.15
Mg	0.54	0.49	0.55	0.49	0.49	0.46	0.47	0.59	0.36	0.49	0.56	0.5	0.59	0.52	0.51
c/fm	1.03	2.26	1.93	1.49	2.39	0.93	3.09	5.38	3.3	2.33	1.75	3.03	3.15	2.84	1.58
Ti	0.29	0.105	0.14	0.12	0.89	0.103	0.103	0.14	0.33	0.19	0.23	0.09	0.17	0.2	0.2
P	0.62	0.51	0.6	0.46	0.29	0.46	0.48	0.35	0.55	0.39	0.42	0.54	0.6	0.38	0.35
Qz	4	-18.54	4.6	-15.65	19.75	-20.62	-1712	17.12	16.92	-15.21	-15.05	-20.76	-30.16	-18457	8.35

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TABLE 2(Contd)

CIPW Norms (Amphibolites)

Mineral	AM 1	AM 2	AM 3	AM 4	AM 5	AM 6	AM 7	AM 8	AM 9	AM 10	AM 11	AM 12	AM 13	AM 14	AM 15
Quartz	—	1.01	9.73	—	3.07	—	—	2	11.13	6.08	12.29	1.3	—	15.72	10.47
Plagioclase	44	38.7	45.09	42.76	47.6	47.06	38.1	42.28	48.64	44.48	36.91	52.27	47.62	41.16	36.62
Orthoclase	5.97	6.03	5.02	5.97	2.72	4.43	1.71	3.01	1.77	2.25	1.95	4.67	3.9	1.83	1.71
Nepheline	4.13	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Corundum	—	—	—	—	—	—	—	—	—	—	—	—	—	1.14	—
Diopside	24.9	24.73	5.13	21.66	4.61	22.54	17.14	7.94	1.91	22.54	17.1	13.29	23.6		20.02
Hypersthene	—	19.01	28.07	17.44	33.47	0.29	24.35	35.01	25.69	15.76	19.81	18.55	3.49	28.51	20.28
Olivine	12.63	—	—	2.02	—	15.04	8.24	—	—	—	—	—	11.78	—	—
Ilmenite	0.85	2.89	1.92	1.58	1.31	2.56	1.77	2.26	5.56	2.09	1.67	4.05	2.53	1.82	0.72
Magnetite	6.05	6.21	4.92	6.47	5.34	6.02	7.6	5.15	4.63	4.92	6.9	5.31	6.61	6.1	6.81
Apatite	0.49	0.58	0.56	0.44	0.42	0.6	0.6	0.65	0.49	0.46	0.51	0.37	0.25	0.44	0.51
Total	**99.02**	**99.16**	**100.44**	**98.34**	**98.54**	**98.54**	**99.51**	**98.3**	**99.82**	**98.58**	**97.14**	**99.81**	**99.78**	**96.72**	**97.14**

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TABLE 2 (Contd)

CIPW Norms (Amphibolites)

Mineral	AM 16	AM 17	AM 18	AM 19	AM 20	AM 21	AM 22	AM 23	AM 24	AM 25	AM 26	AM 27	AM 28	AM 29	AM30
Quartz	6.5	—	6.52	—	15.38	—	—	13.13	13.43	0.58	—	—	—	—	9.4
Plagioclase	44.34	45.84	45.77	45.23	36.08	47.99	43.48	46.72	43.66	35.94	46.49	45.71	38.99	39.28	46.79
Orthoclase	1.83	4.79	2.3	5.38	3.19	5.2	3.43	1.24	3.49	5.56	4.08	3.9	6.62	2.6	1.95
Nepheline	—	—	—	—	—	—	—	—	—	—	—	—	5.21	—	—
Corundum	—	—	—	—	1.06	—	—	—	—	—	—	—	—	—	—
Diopside	19.71	22.57	20.42	19.76	—	18.05	23.84	0.35	8.74	20	15.65	25.59	24.44	17.13	0.3
Hypersthene	18.24	10.11	15.75	17.89	30.46	12.1	16.33	27.14	17.69	26.1	20.76	5.41	—	23.71	32.47
Olivine	—	5.96	—	2.57	—	6.4	0.48	—	—	—	3.44	8.53	13.26	3.74	0
Ilmenite	1.1	2.53	1.98	1.67	2.32	1.06	3.48	5.41	3.21	2.73	1.96	3.48	3.59	3.36	1.69
Magnetite	5.1	6.18	4.71	6.6	6.57	5.94	6.28	4.76	6.54	7.34	6.16	6.61	6.08	7.45	6.7
Apatite	0.67	0.25	0.32	0.3	1.88	0.25	0.28	0.32	0.7	0.49	0.56	0.23	0.44	0.53	0.46
Total	**97.4**	**98.2**	**97.7**	**99.4**	**96.9**	**96.9**	**97.6**	**99.0**	**97.4**	**98.7**	**99.1**	**99.4**	**98.6**	**97.8**	**99.7**

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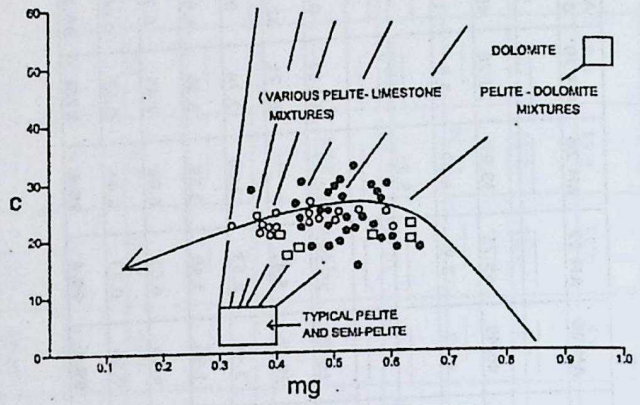
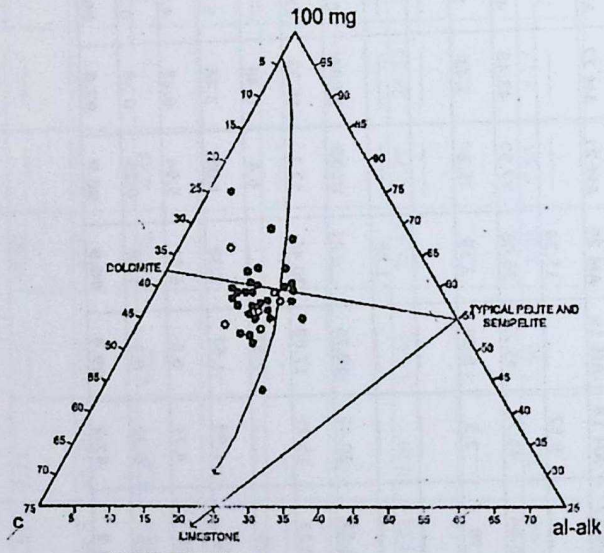


○ ROAN METADOLERITES AND TOECANE ORTHO-AMPHIBOLITES
□ HORNBLENDE SCHISTS (YENKUR)
● AMPHIBOLITES

(Fig. 6) NIGGLI 'mg' AGAINST 'c' PLOT (mg = $\frac{MgO}{FeO+MnO+2Fe_2O_3+MgO}$)
HORNBLENDE SCHISTS AND AMPHIBOLITES FOLLOW THE IGNEOUS TREND OF VARIATION FROM LEAKE (1964)



○ HORNBLENDE SCHISTS
● AMPHIBOLITES

(Fig. 8) PLOT OF "100 mg-c- (al-alk) =100 YENKUR AMPHIBOLITES FOLLOW A TREND CLOSE TO THE KARROO DOLERITE TREND SHOWN AS A FULL LINE TAKEN FROM LEAKE (1964)

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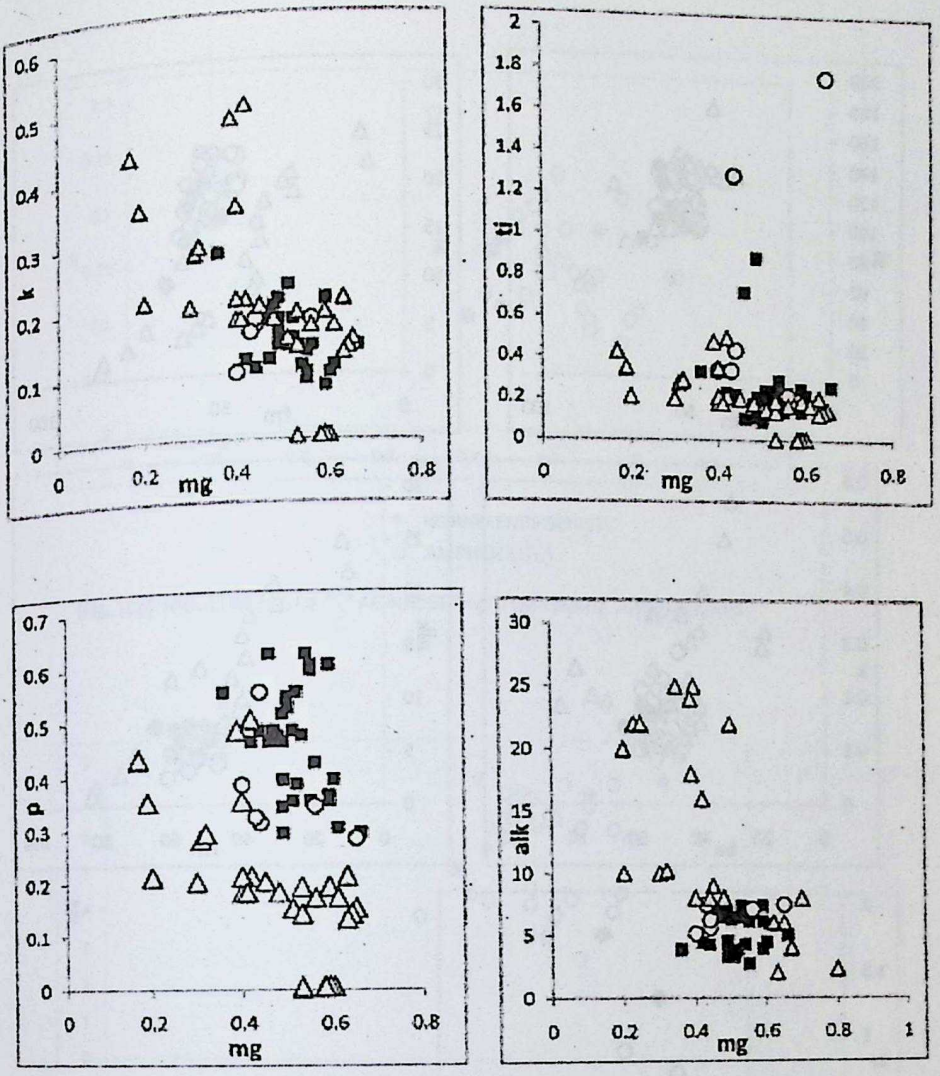

Δ Karoo Dolerites
■ Hornblende Schist
○ Amphibolites

(Fig. 7) Plots of Niggli Values Against (mg).

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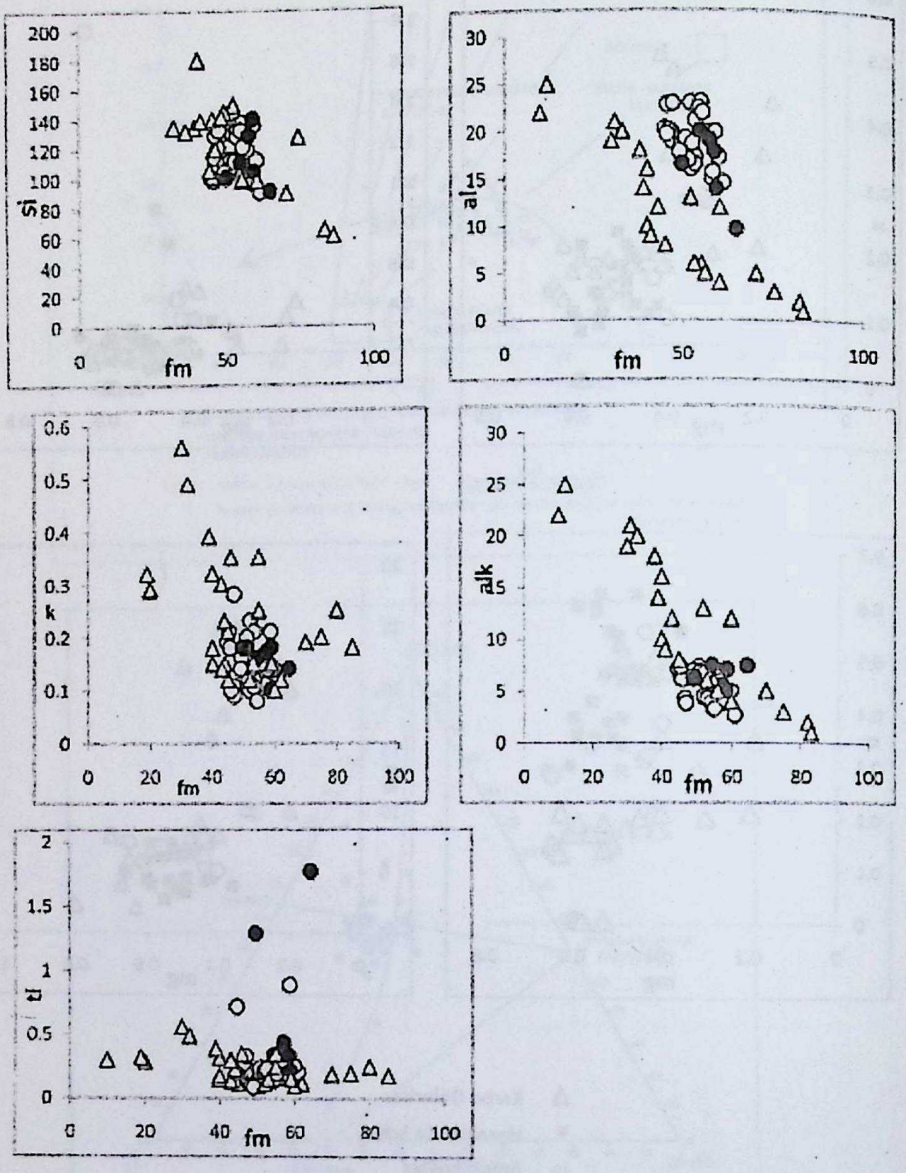

(Fig. 8) Niggli fm Vs si, al, k, alk and ti

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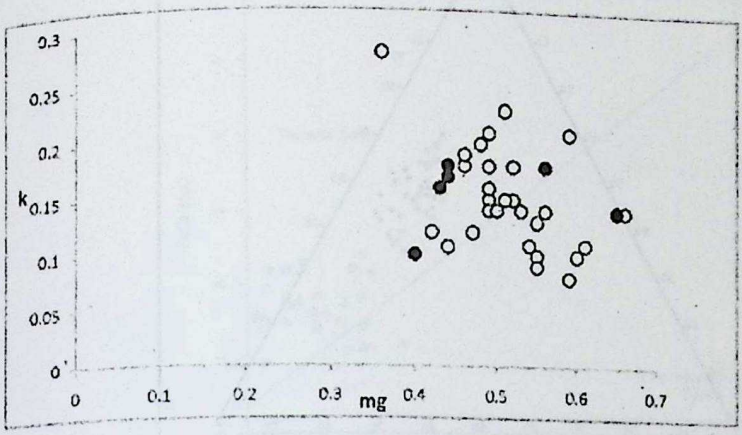
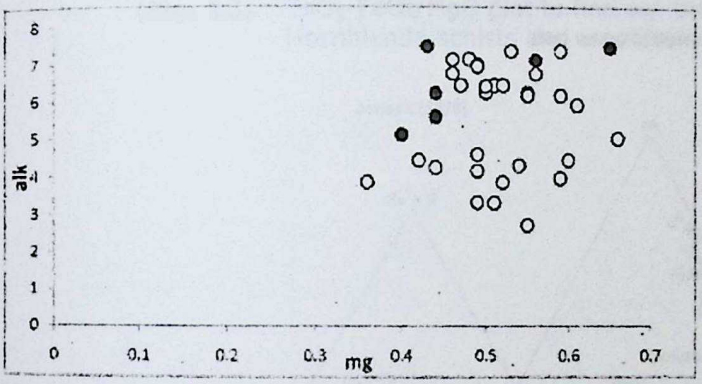


● HORNBLENDE SCHISTS
○ AMPHIBOLITES

(Fig. 10a) NIGGLI PLOTS OF "k" AGAINEST "mg" FOR YENKUR AMPHIBOLITES.



● HORNBLENDE SCHISTS
○ AMPHIBOLITES

(Fig. 10b) NIGGLI PLOTS OF "alk" AGAINEST "mg" FOR YENKUR AMPHIBOLITES.

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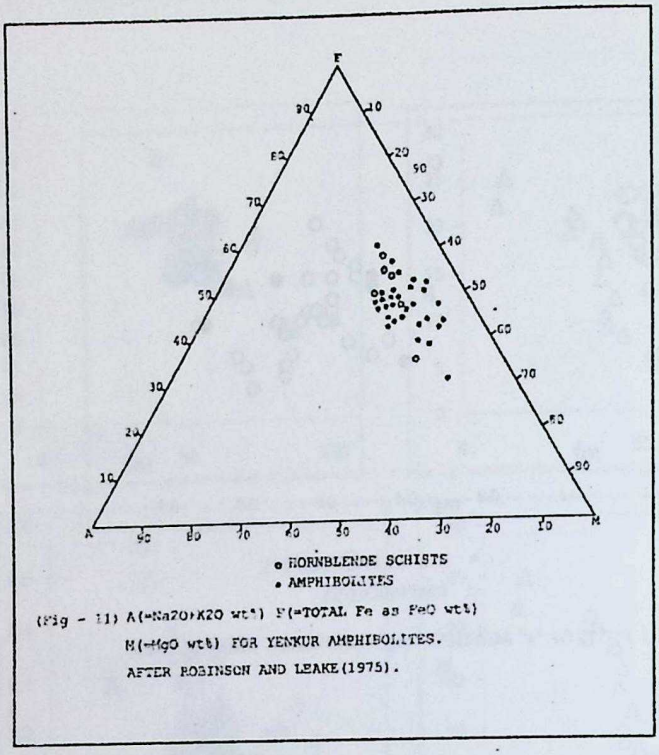
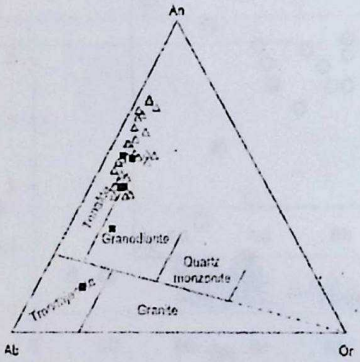


Feldspar triangle (O'Connor 1965)



■ Hornblende schists

Δ Amphibolites

(Fig - 12) An-Ab-Or normative feldspar diagram to know the origin of Hornblende schists and Amphibolites ('O'Conner 1965).

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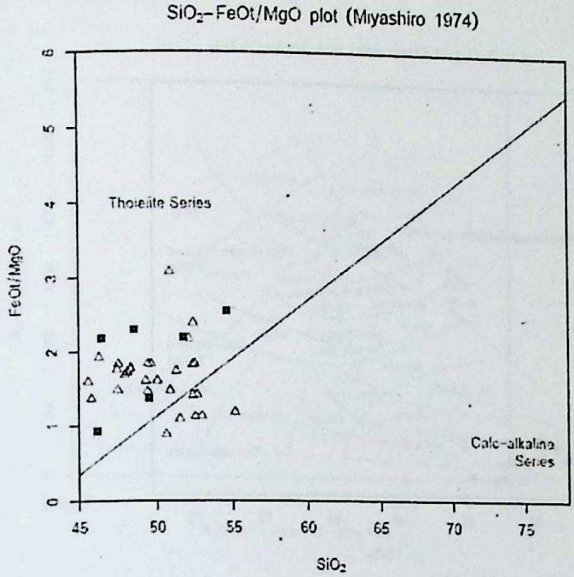
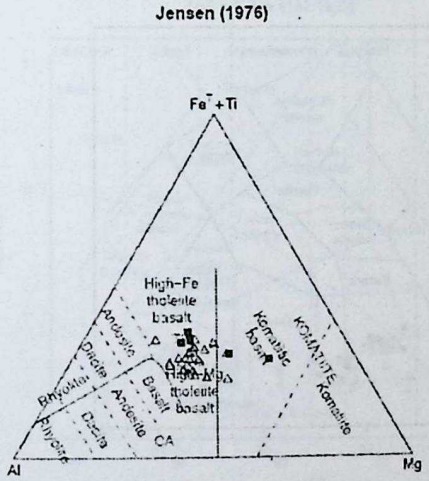


■ Hornblande schists

Δ Amphibolites

(Fig. 13) : SiO_2-FeOt/MgO plot to find out the origin of Hornblende schists and amphibolites (Miyashiro, 1974)



■ Hornblende schists

Δ Amphibolites

(Fig - 14) The cation plot for Hornblende schists and Amphibolites (Jenson 1976).

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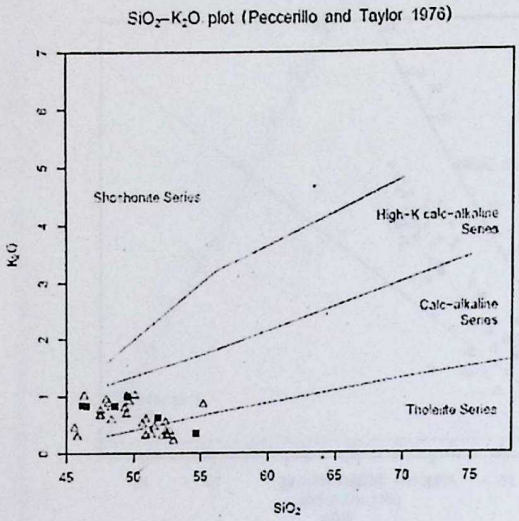
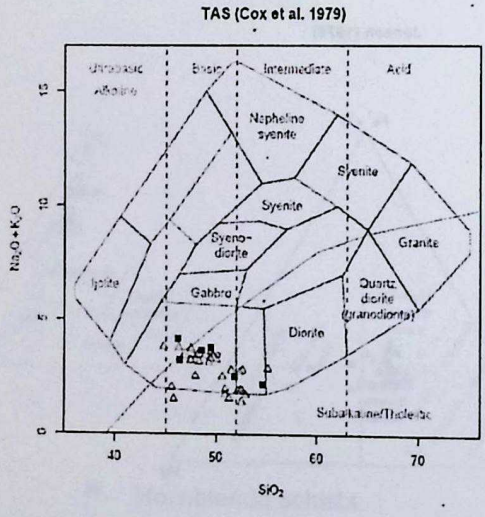


■ Hornblende schists

Δ Amphibolites

(Fig - 15) Plot of SiO_2 against K_2O for Hornblende schists and Amphibolites (Peccerillo and Taylor 1976).



■ Hornblende schists

Δ Amphibolites

(Fig - 16) : TAS diagram using total Alkalies Vs Silica for Hornblende schists and Amphibolites (Cox *et al.*, 1979).

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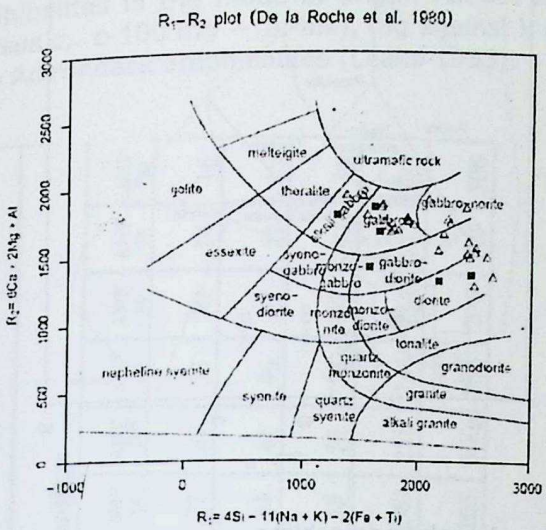
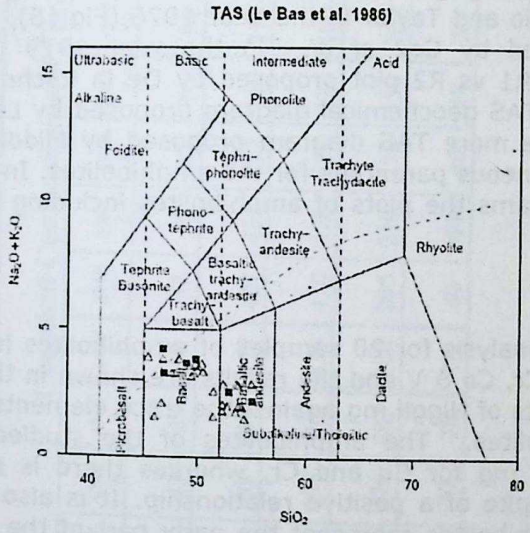


■ Hornblende schists

Δ Amphibolites

(Fig - 17): Hornblende schists and Amphibolite samples from Yenkur region plotted in De la Roche et al., 1980 diagram using parameters R1-R2.



■ Hornblende schists

Δ Amphibolites

(Fig - 18) : TAS diagram using the total Alkalies Vs Silica for Hornblende schists and Amphibolites (Le Bas *et al.*,1986.)

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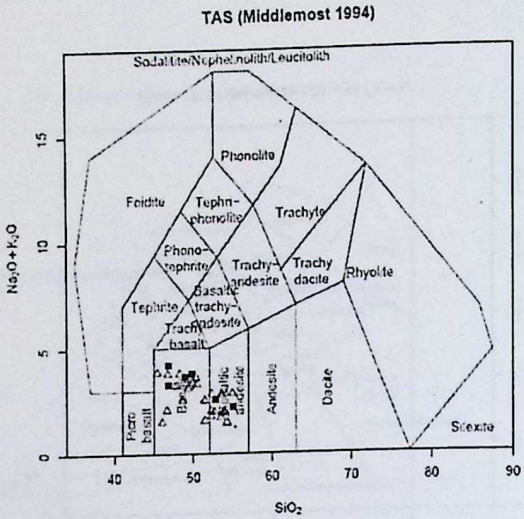

■ Hornblende schists

Δ Amphibolites

(Fig - 19) : TAS diagram using total Alkalies Vs Silica for Hornblende schists and Amphibolites (Middlemost 1994).

A diagram on Feldspar triangle proposed by O' Conner in the year 1965 (Fig.12), another diagram of SiO_2 vs FeOt/MgO plot proposed by Miyashiro in the year 1974 (Fig. 13), other geochemical triangular diagram of Fe^T+Ti-Al-Mg proposed by Jenson in the year 1976 (Fig. 14), one more geochemical diagram SiO_2 vs K_2O plot proposed by Peccerillo and Taylor in the year 1976 (Fig.15), other geochemical diagram of TAS proposed by Cox *et al.* in the year 1979 (Fig. 16), another geochemical diagram of R1 vs R2 plot proposed by De la Roche et al. in the year 1980 (Fig. 17), another TAS geochemical diagram proposed by Le Bas et al. in the year 1986 (Fig.18), one more TAS diagram proposed by Middlemost in the year 1994 (Fig.19), support igneous parentage for the amphibolites. In most of the above drawn geochemical diagrams the plots of amphibolites including hornblende schists fall in basaltic fields.

Trace Elements

Trace elemental analysis for 20 samples of amphibolites have been done for the elements of Ni, Cu, Cr, Co & V and the results are shown in the table number 3. Figure 20, shows the plots of Niggli mg against the trace elements Cu, Co, Ni and Cr for the Yenkur amphibolites. The amphibolites of the studied area show good positive correlation with mg for Cu and Cr, whereas there is some scattering of points for Ni and Co inspite of a positive relationship. It is also observed that the plots of the Yenkur amphibolites represent the early part of the fractionation trend defined by Karoo dolerite.

The inter element relationship of Cr versus Ni and Co versus V, brought out in Fig. 21, indicates positive relationship although some degree of clustering is observed.

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Hornblende schists and amphibolites of Yenkur can be compared with Adirondack amphibolites in the mode of origin. Almost all the geochemical curves such as "mg versus c, c-100 mg – (al-alk), mg against k and mg against alk" are in coincidence with Adirondack amphibolites (Leake 1963).

TABLE 3

Chemical Compositions of (Trace Elements) Amphibolites

	AMP 1	AMP 2	AMP 3	AMP 4	AMP 5	AMP 6	AMP 7	AMP 8	AMP 9	AMP 10	AMP 11	AMP 12	AMP 13	AMP 14	AMP 15	AMP 16	AMP 17	AMP 18	AMP 19	AMP 20
Co	45	48	43	49	59	57	55	62	66	64	68	70	75	73	77	37	35	39	14	16
Ni	90	88	93	95	427	421	431	112	100	114	116	227	224	232	44	41	46	47	21	19
Cr	293	290	298	296	435	430	428	439	183	180	187	540	544	538	55	53	58	53	30	36
V	380	378	376	383	206	205	210	138	156	162	184	183	189	245	240	250	248	134	132	137
Cu	74	72	70	76	78	46	44	40	48	50	98	97	90	101	105	300	288	295	303	308

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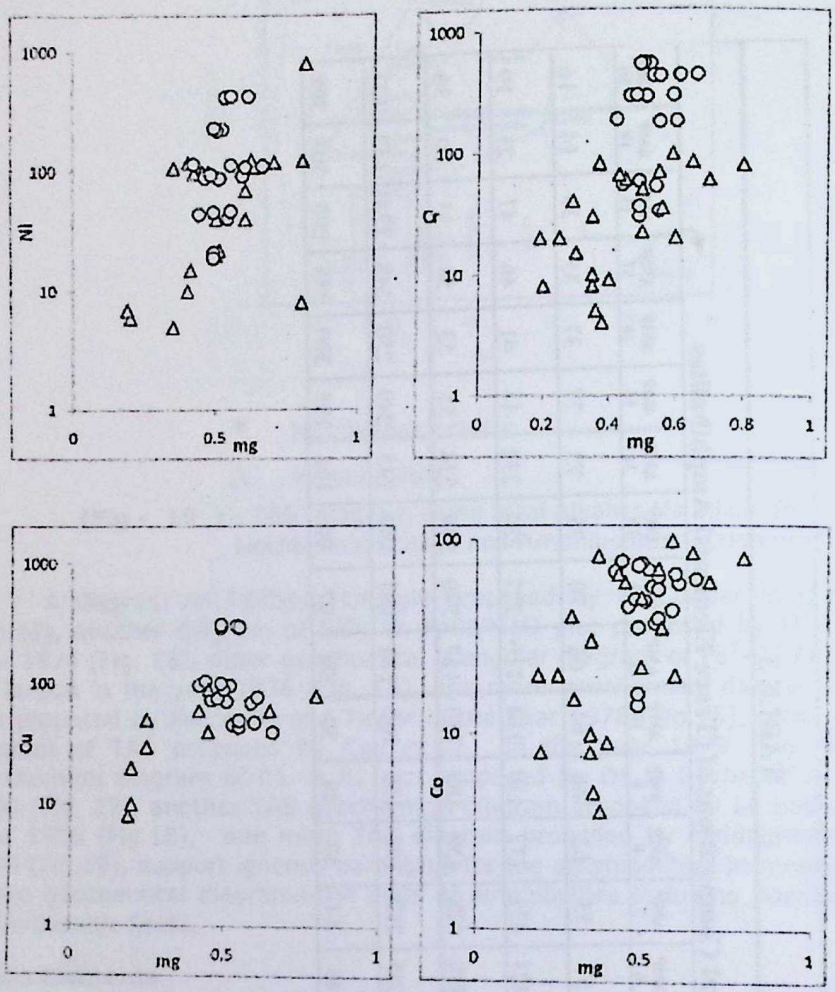

(Fig. 20) Variation of Trace Elements against Niggli Values (mg).

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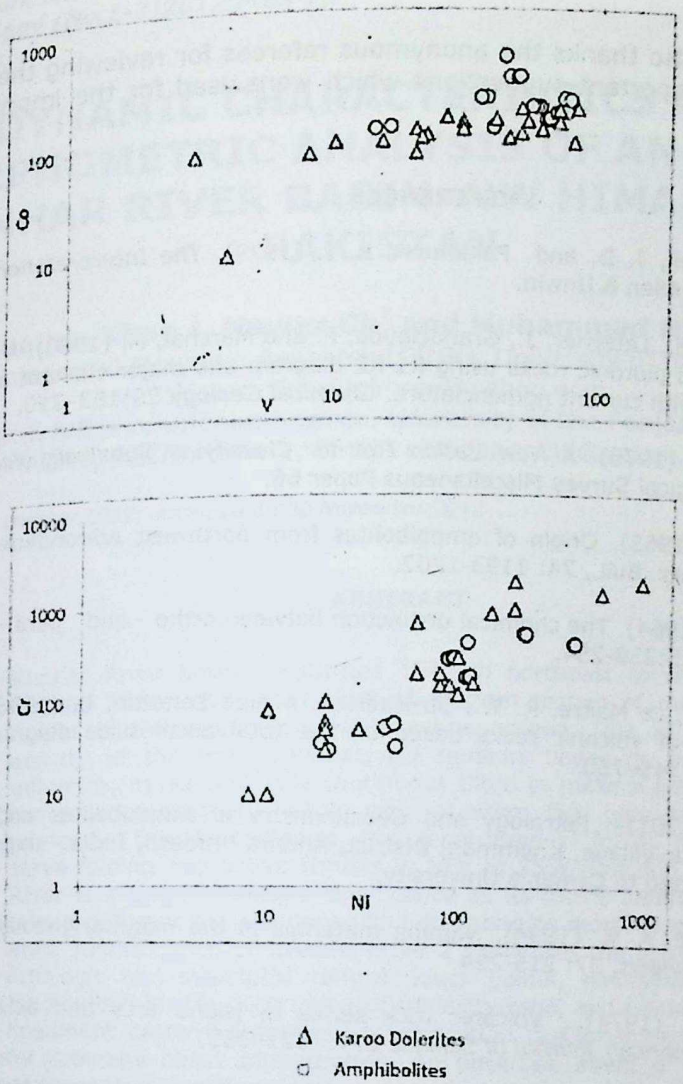

(Fig. 21) Variation of Trace Elements Cr Against Ni and Co versus V.

CONCLUSIONS

Geochemical data and geochemical trends, strongly support the igneous parentage for the amphibolites. Here it is likely that parental basaltic rocks could have been metamorphosed to amphibolites. In this connection the presence of relict pyroxene in some samples of amphibolites would support derivation from the basalts (Malathi, K , 2011).

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The authors also thanks the anonymous referees for reviewing the manscript and making many important suggestions which were used for the improvement of the paper.

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DYNAMIC CHARACTERISTICS AND MORPHOMETRIC ANALYSIS OF AN ACTIVE KUNHAR RIVER BASIN, NW HIMALAYAS, PAKISTAN

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ABSTRACT

Kunhar River basin constitutes 154 km northeast to southwest Kaghan Valley (KV) as a part of western terrain of the Nanga Parbat is the most tectonically active orogen. Due to tectonic activity of the Nanga Parbat, KV remains under its persistent influence; its eastern side continuous tilted to make a high ridge, the snowy peaks and lakes, while western side gets depressed relatively. Due to tectonics, the compressional forces produced serve folding and active thrusts in NEE to SSW direction. Kunhar River is a point of unique significance as its future behavior may take a different pattern depending on changing morphology of the area. Identification of streams order 2 signatures the testimony of lithologic and structural control, knick points, non symmetrical longitudinal profile, high value of sinuosity ratio, and orientation of lineament pattern describes an implication of Cymatogenic uplift for drainage basin configuration. An uncertain event of tectonic movement during Neogene's, a sign of vertical hosting by regional compression is discussed. Kunhar River drains into the Mangla Dam, the second energy producing facility in Pakistan. A detailed morphometric analysis have been undertaken to predict future behavior of Kunhar River so that sustainable evaluation, monitoring and development measures can be taken.

Keywords: Morphometric analysis, Drainage basins, changing morphology, Image processing, Quantitative analysis, Cymatogenic uplift.

1. INTRODUCTION

Morphometry in various aspects of the landform within Kunhar River drainage basin has been described. Law of stream development with a reflection of rejuvenate factor for basin adjustment is capable of analyzing both linear and aerial aspects of the river drainage basin. Identification of streams order Two (2) signatures the testimony of lithologic and structural control, knick points, non symmetrical longitudinal profiles, high value of sinuosity ratio 1.75 (Schumm, 1956, 1973,

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1969b; Schumm *et al.*, 1987 and Vittala, 2004) and orientation of lineament delicate fabric pattern describes an implication of Cymatogenic uplift for drainage basin configuration. Understanding geomorphic features can be based on the negative forces of erosion and the positive forces of tectonics (Pinter and Brandon, 1997; Zeitler *et al.*, 2001a; Zeitler *et al.*, 2001b). Notably, if a specific basin is tectonically unstable; its morphometric analysis acquires extraordinary importance. Such is the case of Kunhar River basin, which constitutes 154 km long northeast to southwest Kaghan Valley as a part of the western terrain of the Nanga Parbat (Khan, 2009). Correspondingly, (Walsh *et al.*, 1998) has described the persistent debris-flow activity along the active Liacher Fault on the western shoulder of the Nanga Parbat. The latter is the terminus zone of the great Himalayas where it adopts a sharp southward bend that affects structural framework of the region. Nanga Pabrat is the most active orogen, which is rising fast. The slopes are exceptionally steep (valley floors 1500 m and mountain peaks 7000 m and above). Consequently, weathering is intense and mass erosion formidable seen as thick valley-fills exceeding 700m or so (Goudie *et al.*, 1985; Goudie, 1990). Fission track data on NW Himalayas over the last 10 years (Zeitler, 1985), shows that it had suffered uplift up to 10 km or so. This has been attributed to its phased uplift and the high rate of erosion. For instance, the total volume of sediment shed into the Indian Ocean over the last 40 million years through the agency of Himalayan drainage system is estimated to be about 8-5 10^6 km^3, giving an annual erosion rate of 0.2 mm/year (Shroder, 1993; Shroder, *et.al.*, 1998; Shroder, *et.al*).

An integrated multidisciplinary and multi-sectoral approach is more essential for sustainable development in mountain areas with limited resources (Khan *et al.* 2009). The study will provide a scientific explanation to better understand the physio-geographic-morphometric environment in the study area and also will contribute source information to reconstruction, rehabilitation and revitalization process in the vulnerable areas.

1.1 Study area:

The Kunhar river drainage basin (Kaghan Valley), an elongated valley 154 km long trends northeast to southwest and lies between latitude N 34°10' and 35°10' and longitude E 73°15' and 74°10' with an area of 2660 km². The valley is bounded by Diamer District and Baltistan on the north, Neelum Valley of Azad Kashmir on the east, Abbottabad District on the south and southwest and Manshera District and Kohistan District on the West. Balakot, Kaghan and Naran are the main towns of the Kunhar River Valley. Considering the total area of the catchments and other characteristics, it can be categorized as a large drainage basin (Figure 1).

Its main geomorphic feature is reflected by an altitudinal difference of nearly 4416 m between its origin near Lulu Sar i.e. Babusur Pass in the NE and the Tori village, 674m, at the origin of Salol Nala with maximum valley slope more than 80%. This gives a remarkable gradient of about 20m per km to the Valley (Khan 2006).

1.2 Research Objectives

- To figure out morphometric analysis and compute the area of various landforms/ land cover for assessment
- Subsequent correlation with data measured on ground at different locations

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- Geospatial datasets exploitation for study of tectonically active mountainous region
- Utilization of satellite Image processing techniques for land cover classification
- Validation of results with the help of ground-acquired alpha-numeric data
- Analyses of results obtained from the employed methods and techniques
- Study of various geo-environmental parameters to seek better options for mitigation.

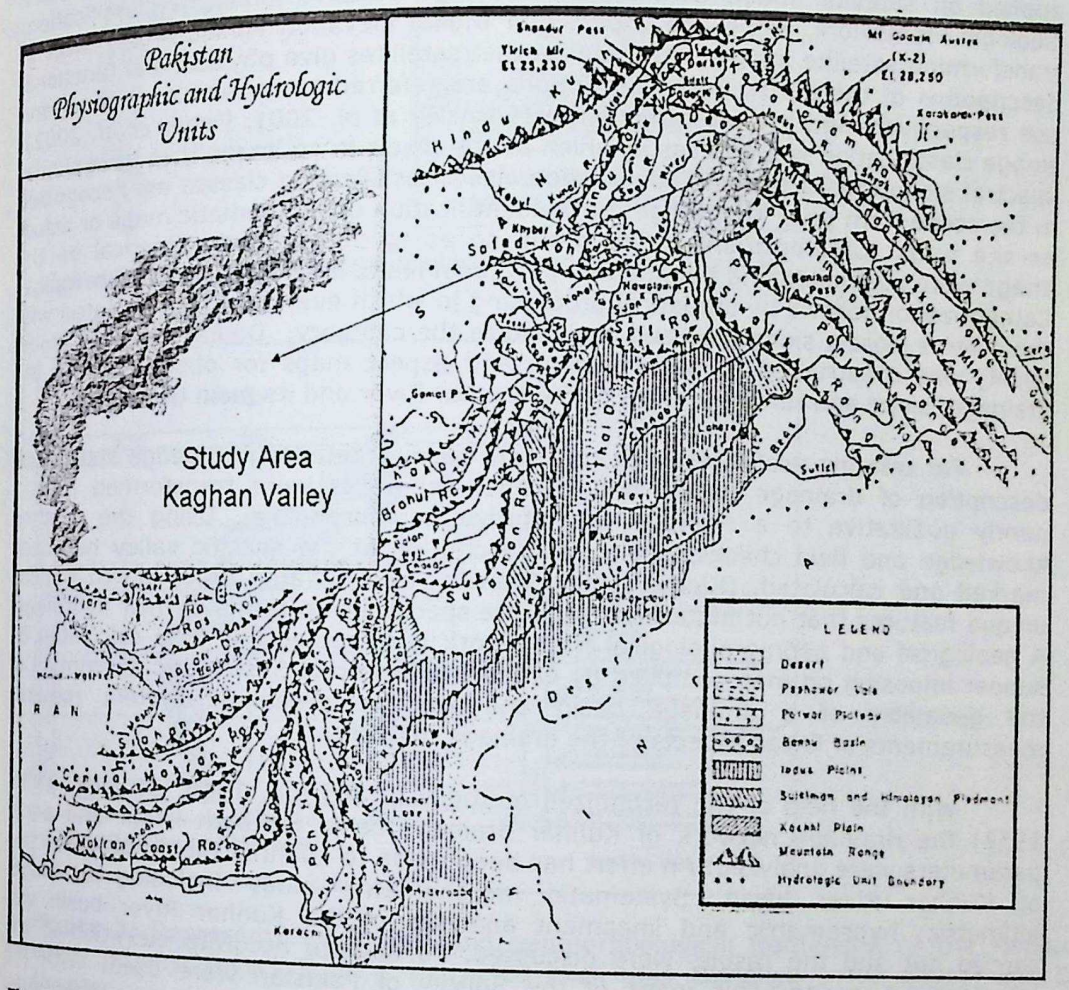

Figure 1: Kaghan Valley (Kunhar River) image map and its location in the northern Pakistan (Source: Geological Survey of Pakistan and Satellite Image).

2. METHODOLOGY

Using the previous information of the study area, training polygons were sketched on the rectified image to exploit later as seed pixels for whole image

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classification. Geospatial datasets were utilized for achieving the current research includes:

a. Topographic Maps, covering the whole Kunhar River Basin.
b. Landsat Images, Thematic Mapper dated 07.10.2001 and Enhanced Thematic Mapper of dated19.09.2009.
c. Digital Elevation Model (DEM): SRTM at 3arcsec spatial resolution.
d. Field Data, acquired from physical survey.
e. Qualitative to a rigorous quantitative morphometric techniques.
f. GIS/RS techniques and graphic software for data presentation.

Having done the preliminary processing and truncation of Geo-spatial datasets on the AOI (Area of Interest), digital image processing techniques were applied on satellite image datasets for drainage pattern, landform classification, Geologic Framework, slope and aspect and Digital Elevation Model. A key facet in transforming satellite images into maps is that satellites give physical and functional descriptions of the earth. Both descriptions are referred to as land cover and land use respectively and are often mixed up (Barnsley *et al*. 2001, Fisher *et al*. 2002). Image classification is a process in which all the pixels in an image that have similar spectral signatures are identified. In supervised classification classes are recognized in the scene from prior knowledge, or by identification using thematic maps or actual on-site visits. Landform/land cover group so as to appear fairly identical on the image were positioned and bounded by polygonal limits drawn on the satellite image. Categorization follows by statistical processing in which every pixel is evaluated with the diverse closest signatures and assigned to the category. Digital Elevation Model (DEM) was constructed to acquire slope and aspect maps for observation of the drainage, slope and terrain profiles of the Kunhar River and its main tributaries.

For creating useful research cum data base, a detailed knowledge and critical description of drainage basins and channel net-works were transformed from a purely qualitative to a rigorous quantitative geomorphology. Using the existing knowledge and field checks, geological description of the specific valley has been marked and calculated. (Kleme, 1990; Krecek, 1996; Wahl, 2000) stated various unique features that put mountains separate specifically in terms of their hydrology. A geological and geomorphological frame work is extracted and area calculated by supper imposing on map compiled by Greco and Spencer. Systematic description of the geometry of a drainage basin and its stream-channel system requires measurements of linear aspects of the drainage network.

With the help of the recognized methods of (Horton, 1945; Strahler, 1956, 1958) the drainage network of Kunhar drainage basin for both linear and aerial parameters were analyzed. An effort has been made to quantify the fluvial dissection of Kunhar River basin. Systematic morphometric study including drainage; altimetric; hypsometric and lineament analyses of the Kunhar River basin was carried out and the results were discussed. To analyze accurate elevation of the intersections, topographic maps of the Survey of Pakistan were used. With the GIS/RS techniques, various data layers have been plotted on the Kaghan Valley map to get reliable information. A total area of about 2,650 km² was selected for classification of land cover classes and demarcation of 19 sub-basins. Based on the prior knowledge of the area the training areas were drawn on the rectified image of the study area, those were later used as seed pixels for entire image classification. Digital Elevation Model was generated on the bases of various data layers. Topographic sheets on a scale of 1:50,000 from the Survey of Pakistan and digital

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three sets of TM data of 2001 and 2009 on a 30m pixel resolution were obtained from the SUPARCO, Pakistan.

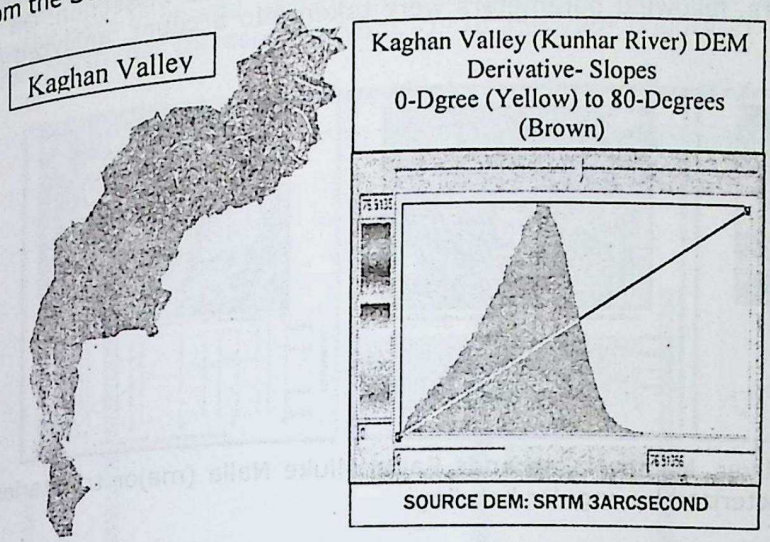

Figure 2: Showing directions of slopes from North in degrees.

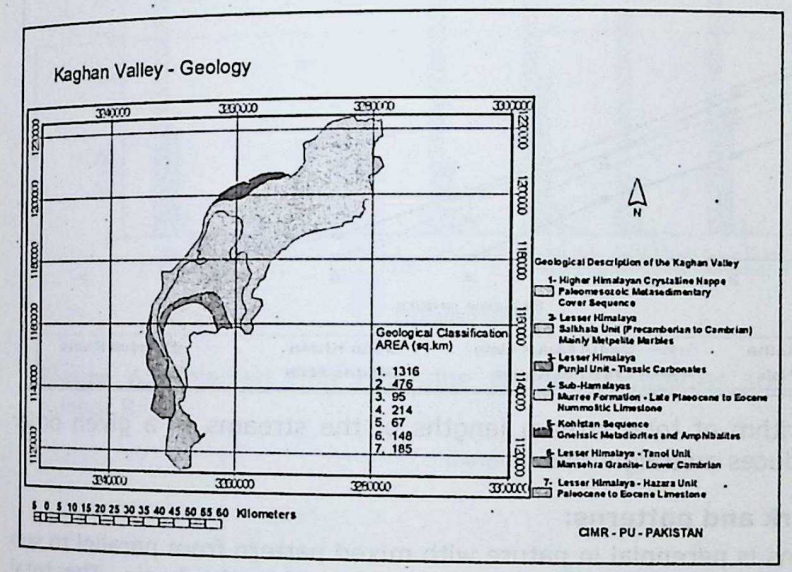

Figure 3: Represents geological and geomorphological framework of the Kaghan Valley (Kunhar River) Source:-Extracted from map complied by A. Greco, and D. Spencer.

3. RESULTS AND DISCUSSION

For half of the world's population, mountains are the main supplier of water. (Price, 1981) and (Wohl, 2000) stated that the degradation processes which modify mountain landforms by weathering, mass movement, fluvial, and glacial action are all united to the distribution and movement of water in liquid, vapor, and solid

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phases. Kunhar River shows a complex geologic framework, erosional and depositional cycles. The present landforms and other geomorphic features developed within the basin are largely the product of erosional/glacio-fluvial dissection. On the basis of above factors, following parameters were taken into account, analyzed and discussed.

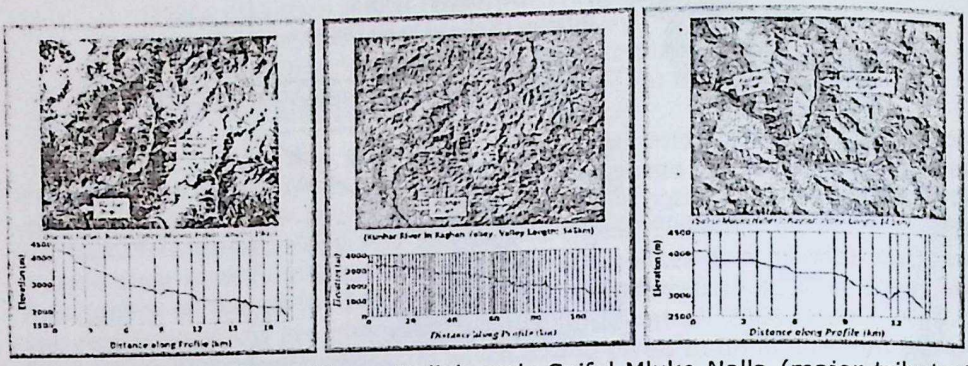

Figure 4: Kunhar River, Manur Nallah ands Saiful Mluke Nalla (major tributaries of Kunhar River) characterized by angular bending.

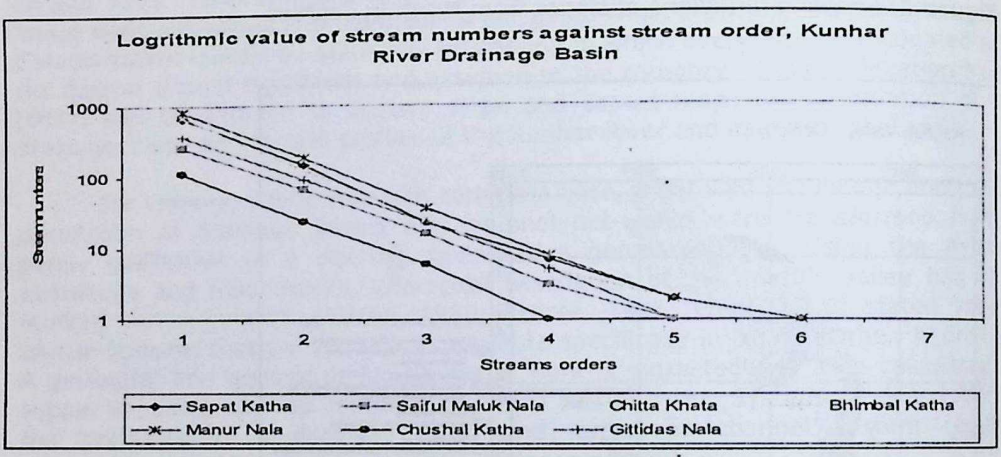

Figure 5: The logarithm of total stream lengths of the streams of a given order against the order produces a straight line.

3.1 Stream's network and patterns:

The network of streams is perennial in nature with mixed pattern from parallel to sub parallel, trellis, and radial and can also be recognized within the basin. The total length of the Kunhar River is about 145 km (Figure 4). Its unique feature is the wide range of altitudinal differences with rainfall varying for 100 mm above Batakundi to more than 2000 mm at Balakot. Above 4500 m, perpetual snow cover is present where glaciers occur and avalanches take place. According to (de Scally ,1992) after the evaporation of slight extended segment of snow deposits, the large volume of snow concerted in narrow valleys and further topographic concavities provide a pocket-sized surface area and so melt gradually. This stored snow plays significant role to the water availability in the perennial streams and also provides a good base for biomass productivity The eastern ridges are covered with perennial snow (above 4500m), and have large number of glaciers and glacial-lakes. Snow deposits have

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been witnessed till October and later in the valley bottom between Kaghan and Naran (Mansell-Moullin, 1986). The general aspect of Kunhar River basin is eastern on the right bank and western on the left bank. Aspect map shows direction of slope from North that corresponds from −1° to 359.996° (Figure 2).

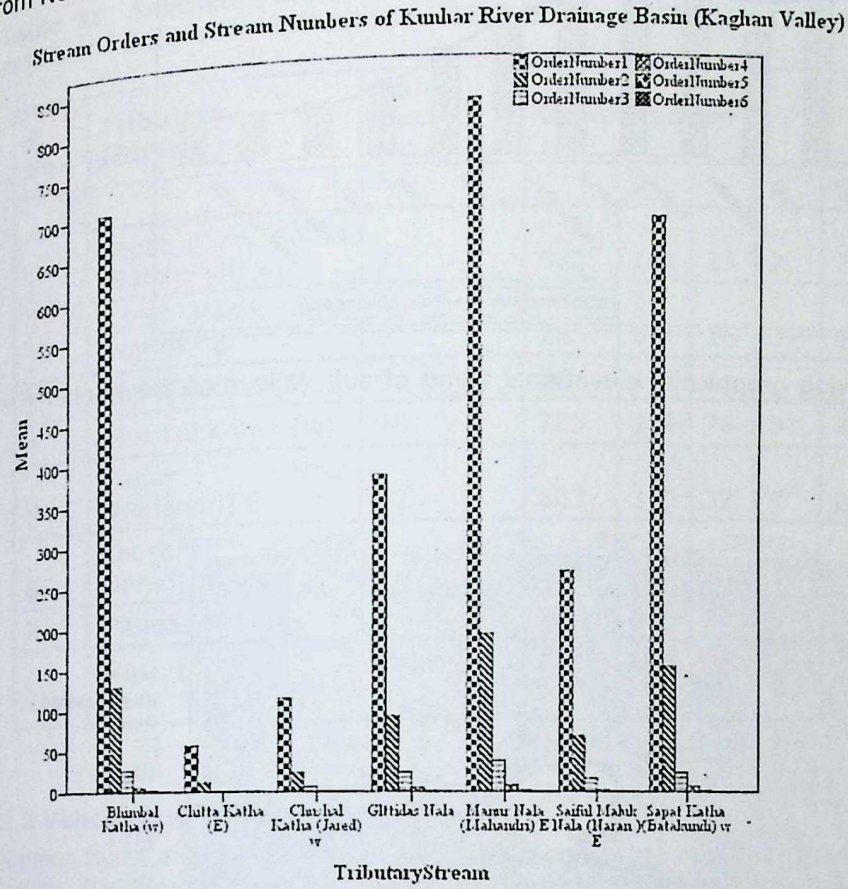

Figure 6: Selected Sub Drainage Basins Tributaries and Order Numbers of the Kunhar River.

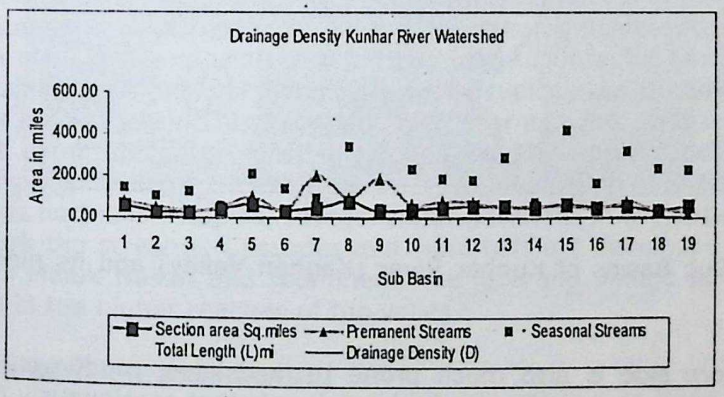

Figure 7: Graphic presentation of Drainage Density/ Stream length ratio against each sub-basin for Kunhar River Basin (Kaghan Valley).

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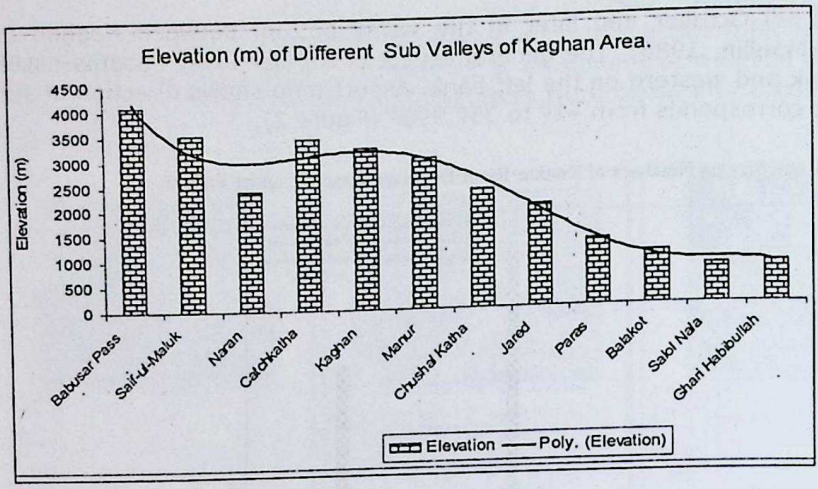

Figure 8: showing graphically elevational trend of sub valleys of the Kunhar River (Kaghan Valley)

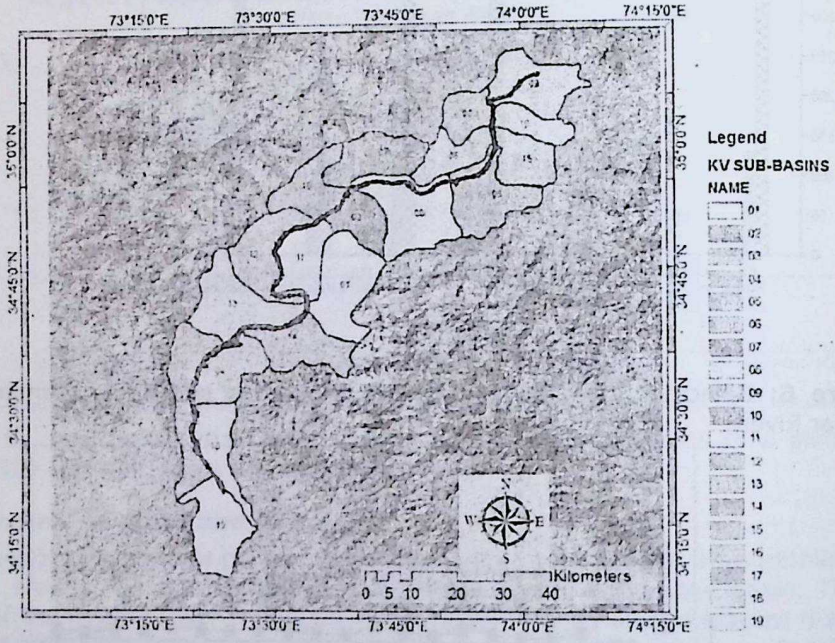

Figure 9: Sub Basins of Kunhar River (Kaghan Valley) and its nineteen micro-sub-basins.

Eastern side is also much prone to landslides, mudflows, snow creep and debris flows, snow avalanches and other hazards that continuously are damaging the infrastructure especially the main Balakot-Kaghan- Babusar and Chilas roadway. Moreover, the site and extent of human activities i.e. infrastructure, dam building,

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agriculture, and mining that put strong influence on landform/ land cover development in mountains are controlled by the distribution of water (Hooker, 1980).

Table 1: Selected tributaries of the Kunhar River drainage basin, their stream orders and Bifurcation Ratio (Rb) for Different no. of Streams (Sub Basin).

S. No.	Tributary (Stream)	Sub Basin No.	Order Number						Rb
			1	2	3	4	5	6	
1	Sapat Katha (Batakundi) w	7	682	151	23	7	2	1	4.5
2	Saiful Maluk Nala (Naran) E	9	263	67	16	3	1	0	3.9
3	Chitta Katha. (E).	9	56	12	1			0	4.8
4	Bhimbal Katha (w)	10	705	129	26	5	2	1	5.5
5	Manur Nala (Mahandri) E	12	823	189	37	8	2	1	4.4
6	Chushal Katha (Jared) w	15	113	24	6	1		0	4.7
7	Glttidas Nala	1	377	91	23	5	1	0	4.1
		Total	3018	663					

3.2 Valleys and Drainage:

Kunhar River and its prominent tributaries constitute sub valleys within the Kaghan Valley. The Kunhar river flows their course from the northwestern extremity of outer flank of Himalayan ranges westward for about 100 km and then suddenly changes its direction towards south at Manur Nala that characterized by angular bending (Figure 4). Near Manur Nala the valley widens its floor with maximum width of about 65 km² and finally proceeds westward near Balakot. After crossing Balakot, the stream turns and flows on a plain land and widens in the bad land topographic feature near Ghari Habibullah. Braided bars and point bars are well developed in the lower reaches of the stream, for a considerable distance, and also near its confluence with the Jhelum River before it enter the gorge west of Lahor Gali. The upper reach of the valley shows a narrow basin, about 50 km from its source Lulu Sar near Babusar Pass to Burawai towards northeast. Rapids, cascades and waterfalls in the upper reach of the valley floor mark the streams. Cascades and waterfalls are developed in the stream bed near Saiful Maluk Nallah and prominent free face and plunge pool. Gorges are also developed in the higher reaches of the valley.

3.3 Tectonic & Geologic Framework:

Kaghan Valley falls between the upper altitudinal zones (Babusar & Lulusar Lake, the origin of Kunhar River) in the Higher Himalayas, while lower zone (Balakot) is in the

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Lesser Himalayas. The tectonic influence of the Nanga Parbat is rather severe and visibly recognizable. (Khan *et. al.*, 1995; 2002) noted that variations in mountain environments over short, horizontal and vertical distances are universally recognized as central to controlling mountain hydrology. Therefore is depicting a remarkable contrast of geo-environment. Just down to Naran The Main Central Thrust (MCT) crosses the Kunhar Valley near Paludran and crosses over the upper part of the Manur nala catchment that originates at about 4400 m asl and joins the main Kunhar River at Mahandri about 1530 m asl. Punjal Thrust (PT), Main Boundary Thrust (MBT) and Main Mantel Thrust (Melange Zone) altogether constitute the major boundary faults. The geomorphology of the Kaghan Valley is largely controlled by very active tectonic forces that are constantly at work in the region. All the major Himalayan Thrusts cross this Valley. The Earthquake of October 8th, 2005 is one of the major tectonic events of this century that impacted a large part in the valley. Paras (1645m asl.), a valley town always remains under the influence of both Panjal Thrust and Main Boundary Thrust as both cross close to this valley town. The Kashmir Boundary Thrust (KBT) and the Indus Kohistan Seismic Zone are within 15 km of Paras. Resultantly, any significant activity on these faults could reshape the valley landforms and impact land use affecting the community..Because of its location close to these active thrusts the area is prone to persistent land sliding. The type of land sliding depends on litho-stratigraphy and tectonics. The events of 8th October, 2005 reshaped the valley and destroyed villages and towns inflicting heavy casualties and loss to property. Kashmir Boundry Thrust (KBT) or Muzzafrabad Fault is an active thrust that crosses Muzzafrabad and Balakot. The epicenter of the October 8th Earthquake was located on this fault. The earthquake triggered hundreds of land slides. The rocks represent a time frame from Pre-Cambrian Salkhalas to Miocene Murree Formation. Structurally, nearly all contacts are faulted. The agglomerate slates appear to indicate volcanic-sedimentary material (Figure 3).

Using the existing knowledge, Geology of the Kaghan Valley (Hazara -Kashmir Syntaxis) has marked on map and calculated as given below:-

1	Higher Himalayan Crystalline Nappe Paleomesozoic metasedimentary cover sequence	52%
2	Lesser Himalaya Salkhala Unit (Pre Cambrian to Cambrian) Mainly metapelites Marbles	19%
3	Punjal Unit Triassic carbonates Melange Zone (Permian to tertiary)	4%
4	Sub- Himalayas Murree Formation (late Paleocene to Eocene) Within layers of nummolitic limestone	9%
5	Kohistan Sequence, Gneissic metadiorites and amphibolites	3%
6	Lesser Himalaya, Tanol Unit, Manshera Granite (lower Cabrian)	6%
7	Hazara Unit, Paleocene to Eocene Limestone	7%

3.4 Quantitative Geomorphology:

The prominent physiogrphic contrast in the Kaghan Valley occurs that affects the vegetation. The eastern ridges are covered with perennial snow above 4500 m, and have large number of glaciers and glacial fed-lakes. This side is also much prone to landslides, mudflows, snow creep and debris flows. Snow avalanches and landslides continuously damage the infrastructure, especially the main Balakot-Kaghan-

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Babusar and Chilas roadway. These glaciers occasionally develop small ponds of snowmelt water that get dammed due to blockage by loose rock material. Where, such glacial ponds due to certain geo-environmental factors get busted, a glacial lake outburst (GLOF) caused rock and mud slurry rushes down the slope causing damage to life, infrastructure and property. After the disastrous September 1992 flood in Kunhar River due to heavy rainfall, another disaster Glacial Lake Outburst struck on 10 July 2001 in the form of Chitta Kataha GLOF that blocked the normal flow by creating mud dam on the Kunhar River for about 11 hours and caused great loss to the property and infrastructure.

To devise a rational (Horton, 1945) first initiated an exceptional idea for stream classification, which is globally accepted followed by (Strahler, 1956; 1992a;Morisawa, 1968; Scheidegger, 1974) accepted this approach to geomorphology as an authenticated and workable approach. More recently, (Wright et.al., 2000; Gritzner et.al., 2001; Marcus, 2002) noted that application of hydrologic modeling could take into consideration geomorphological parameters including stream classification using GIS.

3.5 Stream Orders, Stream Numbers:

For calculating the ordering system of the stream networks of Kunhar River drainage system all small finger tip streams are considered as 1st order and joining two 1st order streams, where length is more in comparison to the first one is given as 2nd order and so on. In these order system, the main stream is put in 7th order and maintains its order throughout the whole course.

However, it is more reliable as it permits a comparison between stream order and structural system. Total number of streams encountered order wise for entire basin was considered. Plot of log value of stream number against stream order produces a straight line (Figure 5) that satisfies Horton's law for this basin. The stream segment of the highest order designated as the main stream is the one through which main discharge of water and sediment have to pass. According to (Strahler, 1956) "order number is dimensionless, two drainage net-works differing greatly in linear scale can be compared with respect to corresponding points in their geometry through use order number". Using these above established parameters, the stream order numbers were given to the selected tributaries of Kunhar River and are documented in Table 1 & Figure 6.

3.6 Bifurcation Ratio (Rb):

Total number of all corresponding stream sub basin is 3,018 while average bifurcation ratios is 4.6. Analyzing the bifurcation ratio, the whole basin varies from 3.9 to 5.5 with 1st order to 6th order stream with a mean value of 4.6. That is a clear indicator of the steep physiographic status of the basin area. On the other hand, bifurcation ratio in the lower order is in constant state (Figure 4). The average bifurcation ratio for 1st order to 4th order streams represents an elongation stage of the basin. The higher bifurcation ratio of 5.5 of 4thorder streams (sub basin) suggests structural or lithological control for drainage basin development (Strahler, 1964; Mekel, 1970; Strahler, 1998).

3.7 Stream Length:

The average length of stream increases with the order in direct proportion. (Strahler, 1958; Strahler, 1964) described that the stream lengths of a given order are inversely proportional to the stream order. The contact between total stream length

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of a given order and the stream order is a power function and plotting the logarithm of total stream lengths of the streams of a given order against the logarithm on the order produces a straight line (Figure 4). Concerning the present study, almost all the values are on the straight line except the 5th order value. This fact might be related to the greater length of particular 6th order streams as compared to the lower order streams due to head ward erosion, which was used on zones of structural weakness.

3.8 Drainage Density:

Drainage density is described as the ratio of total channel length of all orders to the area of the basin (Strahler, 1958). It is an indicator of the closeness of spacing of channels in the basin. At the same time, it highlights the unique relationship between landforms, rainfall, runoff and infiltration capacity. It also gives useful information about the tectonic activity as well as lithologic structure of the basin (Khan, 2002). For this purpose, the basin was sub-divided into nineteen micro-catchments (Figure 9). The acquired data was computed and the results are shown graphically which shows inversely proportional relationship to stream order except the value of drainage density for 15th order basin i.e. 7.0 (Figure 7) . The DD value (7.0) significantly increases and DD value (2.4) decreases due to litho- tectonic and structural control as well as climatic factor of the mountainous region. If the value of DD is less than 5.00, it will depict coarse material, between 5.00 t0 13.70 medium and 13.71 to 155.33 fines and > 155.33 ultra fine soil material respectively. The average drainage density of Kunhar basin is 5.1, which is indicative of coarse and medium category.

The calculated data of the basin shows that the drainage density of the basin is 5.I. However, for individual sub-basin of the Kunhar basin, the lowest density is 2.4 in the basin of 14 and the highest is 7.0 in sub-basin of 15. As a result, the drainage density concerning other sub-basins of the Kunhar river basin ranges between these two extreme values. It is noted that the sub basin areas with comparatively higher density are more prone to erode and have thin vegetative cover with patchy soil cover. The sub basin given number considering elevation of the river basin (Figure 8) that could be observed as polynomial trend of high in the upper reaches, low in the lower reaches, and is the product of fluvial dissection by streams.

3.9 Drainage Basin Area:

For the estimation of run off, the basin area is an important parameter for studying river morphology. The total basin area is divided into 19 sub basins and basin area of each sub basin with stream length is calculated (Figure 9). It is observed that the mean basin area increases as the order of stream increases in direct proportion. The constant of channel maintenance (C) has been calculated as 1,034.4 ft^2. It is observed that the value of C is inversely proportional to the order of stream except for the value of 10th, 15th and 18th order respectively. This factor may also be related to the geotectonic and structural control for the development of the basin. Considering the role of elevation in confiscate water of a basin, the whole basin was divided into half-inch squares and 286 central points of the area were counted.

To assess the time of surface-flow and concentration of rain-fall in stream channels, slope is considered as the most important factor. (Kirkby, 1988) stated that in streams more than 95% of water passes over hill slopes prior to reaching water channels. However, it shows a complex relationship to infiltration, surface runoff, soil moisture and ground water contribution to stream flow.

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4. DISCUSSION AND CONCLUSION

The major objective was to figure out morphometric analysis and compute the area of various land cover for assessment of its subsequent correlation with data measured on ground at different locations for better understanding of the Kunhar River basin. The findings and data presented in the Kunhar River basin study permits to re-evaluate as well as reconstruct the geomorphic background of the northeastern and eastern part of NW Himalayas folded region, on which Kunhar River basin of the Kaghan Valley has emerged. The physiographic elevation is evident due to glacio-fluvial erosion that took place due to geotectonic uplift of the Himalayas. A elevational difference of about 4900m between its origin near Babusar Pass in the NE and the Tori Village 674m asl at the mouth of Salol Nala is a clear indicator of geotectonic activity (Khan, 1998; Khan *et al.*, 2002; Khan *et al.*, 2006). Loessic plain at the western part i.e. Shongran and Lalazar are the prominent planer surfaces. Other small planer surfaces establish signature of the surface erosion. Besides, many earth scientists, (Devantier *et.al.*, 1993) emphasized Digital Analysis Models; the best utilization of elevation data is by using point, contour line or triangulation networks.

A detailed systematic analysis of the drainage system reveals the significant role of the glacio-fluvial processes in accordance with the various laws of Geomorphology formulated by (Horton, 1945). A long-term process of fluvial dissection is largely responsible for the development of valley floor. A tectono-structural control in the development of stream channel is evident from straight segments of streams and sharp angular turnings in sinuous bends and knick points along with entrenched meandering. This suggests that the basin has undergone rejuvenation largely due to Cymatogenic uplift. Hypsometric analysis supports the conclusion that the Kunhar river basin as a whole represents the "monadnock" stage of creation. The occurrence of knick points marked by cascades and waterfalls above 4000′ supports this conclusion.

Lineaments identified on Landsat's Multi-spectral Imagery datasets, acquired using both Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM) Sensors, correspond to linear zones of tectono-structural weakness. The lineament patterns for the entire river basin indicate that deformation as well as restructuring has been the outcome of combined regional compression and vertical hosting (Power *et al.*, 1980). Tectonic movements might be the dominant cause for deformation and restructuring of layers of rocks for the formation of mountainous ranges. Straight segments related with higher order streams could be inferred as structurally controlled for their development. The deformation within Kunhar River basin is related to India-Asia collision and subduction of Indian Plate under Asian Plate. Analyzing the bifurcation ratio, the whole basin varies from 3.9 to 5.5 with 1st order to 6th order stream with a mean value of 4.6. That is a clear indicator of the steep physiographic status of the basin area. The average bifurcation ratio for 1st order to 4th order streams represents an elongation stage of the basin. The higher bifurcation ratio of 5.5 of 4th order streams (sub basin) suggests structural or lithological control for drainage basin development (Schumm, 1956, Strahler, 1964, Mekel, 1970 and Strahler, 1998). Presence of river terraces in the upstream, knick points, waterfalls, gorges and rapids are indicative of rejuvenation. This rejuvenation is related with geotectonic movement in that region during Neogene time. The value of sinuosity index of the Kunhar River and other sub order streams of this basin are above 1.5 which is indicative of entrenched meandering; an indication of rejuvenate

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stage of basin development. Study also has also opened various avenues for developing an enhanced strategic planning and mitigation measures.

Considering the dynamicity of Kunhar River, demand has increased in interdisciplinary and multidisciplinary planning to meet the multifaceted challenges that have been intensified to a critical stage. Mountains behaves like "natures own laboratory" and as a principle, mismanaged experiments from any laboratory will hit back and create havoc. Devastating earthquake of 8th October, 2005 is an example of ill-planned exploitation of natural resources.

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TRACE ELEMENTS AND THEIR TOXIC EFFECTS IN THE GROUND WATER OF PATANCHERU INDUSTRIAL AREA OF ANDHRA PRADESH

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ABSTRACT

Adverse environmental effects are observed with redistribution of trace elements in groundwater in Patancheru Industrial area by different product manufacturing industrial operations, their improper storage and indiscriminate disposal of their process generating effluents, atmospheric combustions of fossil fuels, municipal domestic sewage, disposal on land and their runoffs during rainy season becoming a path way of infiltrations of contaminants in to the groundwater through soil profile. This study reveals that the evaluation of non-essential trace metals like Ar, Cd, fe, Cr, Ni, Pb, Hg, and Zn depending on their sensitivity, residential, non-residential areas and their contaminations vary from location to location, based on their schematic percolations of contaminations into the groundwater table. Further investigations to be carried out on the potential hazards to human body when consumed this groundwater as drinking purpose in these areas.

Keywords: Trace elements, Groundwater, Contamination, Percolation, Industrial area.

INTRODUCTION

The trace elements have an essential role in the metabolism and growth of an individual in their biotic life. A good variety of physico-chemical pollutants have been identified in the environment, which are polluting the ground water due to industrialization, over population or urbanization and also due to the modern technology in this century. B, F, Si, V, Cr, Mn, Fe, Co, Mo and Sn are the essential trace metals. Trace element content of a soil is dependent almost entirely on the rocks from which the soil parent material was derived and on the process of weathering. Pollution caused by heavy and trace elements is a worldwide phenomenon. Increased levels of trace materials in ground water cause more concern due to the possibility of accumulation, which causes phyto-toxicity and carcinogenic. Trace elements in ground water cause only local pollution which depends upon the anthropogenic activity. The environmental significance

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can be assessed in terms of degree of concentration of trace elements, their toxicity and the extent of exploitation in ground water table. Some of the trace element such as Ar, Cd, Cr, Fe, Hg, Ni, Pb, Zn are evaluated at Patancheru industrial area of Andhra Pradesh. The presence of metals and metalloids in potable water is a subject of serious concern due to toxic properties of the metals (Ashton and Chan, 1987; Barua *et al* 2001). Though the heavy metals occur in aquatic environment as a result of weathering and land drainage, recent years the increasing load of sewage discharges, dumping of industrial wastes, effluents and agricultural runoff have further increase the levels in aquatic environment.(Godwin Wesley, 2004).

MATERIALS AND METHODS

The study area located/covered the Patancheru industrial area geographically represented by the 17^0 30' to 17° 35' N latitude and 78^0 10' to 78^0 15' E longitude of Medak district, Andhra Pradesh, India.

Groundwater samples were collected from bore wells, from up and down streams at 20 sampling sites. Seven locations were chosen based upon the sensitivity, residential and non-residential areas and major anthropogenic affecting areas as represented in figure-I. groundwater samples were collected in three sampling sites of each location at moderate climatic condition in 1Lt acid washed polypropylene cans by grab sampling techniques and acidified with 1ml of $ARHNO_3$, in the field in each station and immediately sealed with label along with relevant details and analysed for As, Cd, Cr, Ni, Hg, Pb by the advent analytical instrument AAS (AVATIS-GBC) by following copreciption, solvent extraction, ion exchange and reduction in volume by evaporation adsorption procedures in prescribed way to determine the concentration of elements of each sample done in replicate. Extreme care was taken during the analysis of the samples as to avoid the contamination and purification of reagents used since they contribute high blank levels. Estimation of blanks and standard samples of known concentration analysed by adopting the, standard procedures for water and waste water analysis (APHA-1992).

RESULTS

Results were tabulated in table 1,2,3,4.

The analyzed water samples from Patancheru industrial area were recorded. The presence of trace element concentrations of As, Cd, Cr, Hg, Ni, Pb are shown in table-I, evaluated by AAS (AVATIS-GBC) in all the sampling sites and compared with world health organization (WHO) standards for drinking water quality. The chromium, in the water sample ranged from 0.01 to 0.30 mg/L with an average of 0.14 mg/L, lead ranges from 0.01 to 0.06 mg/L with an average of 0.011 mg/L Zinc ranges from 0.01 to 0.18 mg/L with an average of 0.0375 mg/L and Nickel ranges from 0.01 to 0.011 mg/L with an average of 0.031 mg/L, Iron ranges from 0.01 to 1.73 mg/L with an average of 0.36 mg/L where as Cadmium and Mercury was found below the detectable levels (<0.01 mg/L) which was not prescribed in any of the standard drinking water quality. Among these trace elements Cr and Fe predominately at higher levels when compared to other elements in groundwater. In between these Cr is predominantly found in higher concentration at 16 sampling sites S-2, S-3, S-4, S-5, S-6, S-7, S-8, S-9, S-10, S-11, S-12,

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Table-I
ANALYSIS OF GROUNDWATER SAMLES AT DIFFERENT LOCATIONS OF THE SAMPLING SITES AROUND PATANCHERU INDUSTRIAL AREA, MEDAKDISTRICT ANDHRA PRADESH, INDIA.

Trace elements	Fe	Cd	Ni	Zn	Pb	Cr	As	Hg
WHO standards For drinking water quality	1.0	0.01	-	-	0.1	0.05	0.05	0.001
LOCATION								
L-1								
S-1	0.09	<0.01	0.04	0.06	<0.01	0.02	<0.01	<0.01
S-2	<0.01	<0.01	0.04	0.03	0.06	0.13	<0.01	<0.01
S-3	0.02	<0.01	0.06	0.02	<0.01	0.15	<0.01	<0.01
L-2								
S-4	0.28	<0.01	0.02	0.03	<0.01	0.11	<0.01	<0.01
S-5	0.73	<0.01	0.01	0.02	<0.01	0.18	<0.01	<0.01
S-6	1.15	<0.01	0.03	0.03	0.02	0.20	<0.01	<0.01
L-3								
S-7	0.09	<0.01	0.11	0.02	0.01	0.01	<0.01	<0.01
S-8	0.09	<0.01	0.02	0.02	0.02	0.18	<0.01	<0.01
S-9	0.05	<0.01	0.06	0.03	0.01	0.02	<0.01	<0.01
L-4								
S-10	1.3	<0.01	0.03	0.02	0.01	0.17	<0.01	<0.01
S-11	0.19	<0.01	0.03	0.01	<0.01	0.13	<0.01	<0.01
S-12	0.01	<0.01	0.02	0.14	<0.01	0.25	<0.01	<0.01
L-5								
S-13	0.18	<0.01	0.04	0.05	0.02	0.30	<0.01	<0.01
S-14	0.12	<0.01	0.02	0.18	0.01	0.20	<0.01	<0.01
L-6								
S-15	0.01	<0.01	0.05	0.07	0.01	0.01	<0.01	<0.01
S-16	0.36	<0.01	0.01	0.01	0.02	0.20	<0.01	<0.01
S-17	0.23	<0.01	0.02	0.01	0.02	0.12	<0.01	<0.01
L-7								
S-18	0.01	<0.01	0.01	<0.01	<0.01	0.18	<0.01	<0.01
S-19	1.73	<0.01	<0.01	<0.01	0.02	0.21	<0.01	<0.01
S-20	0.21	<0.01	<0.01	<0.01	<0.01	0.19	<0.01	<0.01

All values are expressed in mg/l
L=location
S=sampling stations

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Table-2: MEAN VALUES OF SAMPLING SITES AT DIFFERENT LOCATIONS

Location	Fe	Cr	Ni	Zn	Pb
L-1	0.04	0.10	0.04	0.036	0.026
L-2	0.72	0.163	0.02	0.026	0.013
L-3	0.07	0.07	0.06	0.023	0.013
L-4	0.50	0.183	0.026	0.056	0.01
L-5	0.15	0.25	0.03	0.115	0.015
L-6	0.20	0.11	0.026	0.03	0.016
L-7	0.65	0.193	0.01	0.01	0.013

*All Values Are Expressed in mg/L

Table-3 : GROUNDWATER CONTAMINATION SEQUENCE ORDER FOR DIFFERENT LOCATIONS

Contamination sequence order	1	2	3	4	5	6	7
Fe	L-2	L-7	L-4	L-6	L-5	L-3	L-1
Cr	L-4	L-6	L-3	L-1	L-5	L-2	L-7
Ni	L-4	L-1	L-2	L-3	L-5	L-6	L-7
Zn	L-1	L-6	L-5	L-2	L-3	L-7	L-4
Pb	L-5	L-7	L-4	L-2	L-6	L-1	L-3

S-13, S-14, S-15, S-16, S-17, S-18, S-19, and S-20 with an average of 0.18 mg/L where as drinking water quality prescribed by WHO was 0.05 mg/L and exceeded the levels 3.6 times than WHO was 0.01 mg/L and exceeded the levels 13.9 times than WHO standards. Results were tabulated (table 1, 2, 3, figure 1&2) Graphical representation of concentration of elements in Patancheru industrial area is shown in figure-2.The mean values of trace elements at different locations are calculated and tabulated in table-2. Moreover the sequence order was given for each locations depending on the contamination levels i.e., lower sequence order given to higher contaminated location and higher sequence order to lower contaminated location vice versa were tabulated in table-3. From the data obtained in table-1 and 2 scoring was given for each location in which overall elemental contamination was more are tabulated in table-4. The lower scoring

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represent high score represent the low contamination location. Finally the overall groundwater contamination sequence order was given for different locations as below.

Table-4: MEAN SCORE OF GROUNDWATER CONTRAMINATION

Contamination for location	1	2	3	4	5	TOTAL
L-1	7	4	2	1	6	20
L-2	1	6	3	4	4	18
L-3	6	3	4	5	7	25
L-4	3	1	1	7	3	15
L-5	5	5	5	3	1	19
L-6	4	2	6	2	5	19
L-7	2	7	7	6	2	24

DISCUSSION

GROUNDWATER CONTAMINATION SEQUENCE ORDER OF LOCATION

L-4>L-2>L-5>L-6>L-1>L-7>L-3

The studies were carried out during summer season. The highest concentration of chromium lead and Iron recorded in the groundwater samples during the study, could be attributed to the indiscriminate discharge of wastes from leather, tannery explosive, plywood manufacturing industries, paint pigments, dyes, textile industries are major source of water pollution by soluble chromium salts in process and Iron from their structures, building material sources are the sources of groundwater contamination. Especially fertilizer industry the fertilizers which contain several 1000ppm of Cr in which phosphate contains high levels, Cr around 100mg/kg (Krishnan Rao.,2001). Increase in heavy metal concentration at Patancheru industrial area has been reported by Shiva Kumar et.al., (1997).The observation made by Subba Rao et.al., (1998), Subramanyam and Yadaiah, ,(2000),GurunadhaRao, et al (2001) and Madhavi et al., (2003) on metal pollution load on water bodies, further supports our findings.

US-EPA suggests that the total Cr limit of 0.05 mg/L in domestic water and should always be <0.05mg/L in drinking water where as in rain water to be 0.003 mg/L and in groundwater <0.03 mg/L. In spite of this in the industrial area of Patancheru, groundwater is severely polluted and if we consume the ground water for domestic utilities which tend to effect dermatitis, allergy, especially skin allergy, gastro-intestinal

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ulcers. Irrespective of these biochemical effects if these are at normal levels, intake into human body will play an important role in insulin metabolism as GTF (glucose tolerance factor) helps to normalize and improve glucose tolerance in diabetics, older people and malnourished children at normal levels.

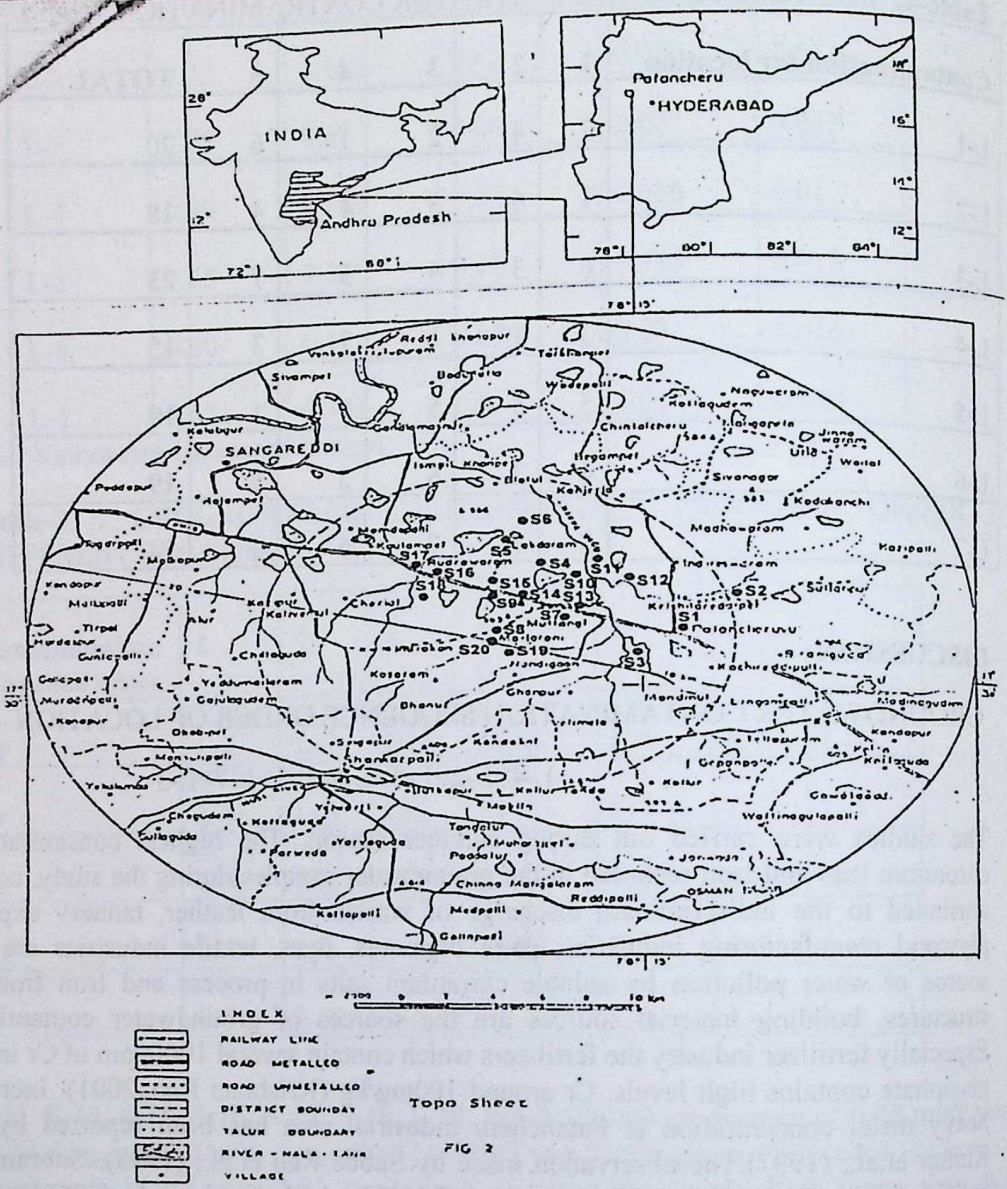

Figure-2 : India map showing Andhra Pradesh state-Patancheru Industrial area..

Where as in the deep tube wells Iron exists as ferrous ion which on taking out rapidly changes to light yellow orange color due to oxidation and precipitation to ferric

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hydroxide. Paliwal (1976) reported that such wastes are extremely harmful for drinking purposes as permissible limits of Iron is only 0.3 mg/L and also it effects on domestic use, water supply structures which promotes the growth of Iron bacteria which also implicates in physiological disorders like drozing akiochi, seana disease and folion diseases in tobacco. (Freiberg I., G.F, Nordberg and V.Vouk 1980 hand book of toxicology of metals, Elsevier,N.Y) for the cultivation of low land rice. Irrespective of these adverse effects Iron intake into human body forms is an essential component of several enzymes and structures including, Hb and cytochromes.

Arsenic (As) is a part of earth's crust and occurs naturally in some soil rocks and can reach into groundwater, despite its notoriety as a deadly poison, arsenic, is an essential trace element for some animals., the necessary in take is as low as 0.01 ppm/dy WHO 2006. Causes irritation in stomach and intestine.

Cadmium (Cd) cadmium is a transition metal along with ZN and HG cadmium is lustrous, silver white, very malleable metal. Causes damage filtering mechanism of kidney.

Iron (Fe) fe is a VIII group element of periodic table. Tenth abundant element and is exists in four distinct forms. Most of the iron is formed in various Iron oxides Iron deficiency is the body causes anemia, weakness and fatigue.

Lead (Pb) one of the ancient metals used by human lead in very soft highly melleable, ductile and poor conductor of electricity. Lead occurs naturally in the environment lead in highly toxic metal. When exposed cause a variety of neurological disorders.

Manganese (Mn) is a hard metal and is very brittle will react with water Mn is a most abundant metal in soil. It is necessary for human survival. It is also toxic when taken in high concentration. In human body 0.05 ppm/dy WHO (1993). According to Grant (1980) Mn effects respiratory track and also the brain when men are exposed for a longer period of time and also the men may become impotant.

Mercury (Hg) a common metal liquid of room temperature. It is rare in earth's crust. It is heavy, silver white liquid metal. Hg is a compound can be formed naturally in the environment. Effects disruption of the nervous system damage to brain DNA and chromosomal damage.

Nickel (Ni) ni is found to be present in igneous rocks, soils, coal, crude oil, with an average concentration in earth crust is 75 ppm. Plants are known to accumulate Nickel. smokers would retain high nickel concentrations in their lungs respiratory irritants and my cause preumonitis.

Selenium (Se) is a non metallic chemical element. In chemical and physical properties it resembles sulphur and Tellurium. Se is a rare element on the surface of the planet. It cause dizziness, fatigue and irritations of the mucous membrane when the exposure in extremely high, collection of fluid in the lungs and bronchitis may occur, brittle hair,

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deformed nails, swelling of skin and severe pains. Se naturally present in grains, cereals and meat.

Zinc (Zn) zinc is a lustrous white metal. Zn is the 23rd most abundant element in the earth's curst. Less Zn- experience lose of appetite, decrease sense of taste and smell, show wound healing. Extensive exposure may cause respiratory disorders.

CONCLUSIONS

The results clearly indicating that the groundwater aquifers at an objectionable quality producing an objectionable taste odour by the indiscriminate disposal of the wastes generated from the industrial complexes in and around Patancheru industrial area are aggrevated the trace element concentrations in the groundwater. Effective technologies for implementation, civic sense among the industrialists, hundreds to thousands of years takes for contaminated groundwater to clean itself of degradable wastes and non-degradable waste will be there permanently reflects the chemical and organic pollution. Because of non visibility, leading to the pollution load on the water bodies. The government authorities and also the entrepreneurs should take necessary steps to curtail the indiscrimate dumps of effluents, hazardous wastes on land and deep well injections of effluents. Each and every person must be aware about environment and contamination having moral responsibility to conserve and restore the groundwater resources for future generations.

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APPLICATION OF BAYESIAN STATISTICAL INFERENCE FOR PREDICTION OF WATER QUALITY FOR RIVER MANAGEMENT

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ABSTRACT

New forecasting method in Water quality prediction can provide realistic estimates of prediction errors and therefore increase the efficiency of river basin management. Safety margins for restoration measures and accompanying targeted pollutant load limits are important parameters in river basin management. To have two methods in water quality prediction approaches including mechanistic and statistical, we uses Bayesian statistical inference and MCMC methods. A hierarchical modeling strategy is employed in order to pool information from extensive cross-sectional lake monitoring data and consequently to improve the accuracy and precision of lake specific water quality predictions. The result of testing using extensive hydrological and water quality data from five world river basin management show even models with large numbers of correlated parameters can be fitted using modern computational methods.

Keywords: River basin management, Target pollutant load, Bayesian inference, MCMC, Hierarchical model.

1- INTRODUCTION

The availability of clean water and the good ecological status of surface waters have been endangered by increasing loads of nutrients and chemicals. Planning and implementation of water management will be organized on a river basin basis in order to ensure that local factors and the need for water protection measures are taken into account efficiently. Ecological and chemical protection is required everywhere, but other forms of protection will apply only within specific zones.

The targeting of the required pollutant load reductions and the finding of technical solutions for their implementation are the challenging key ingredients of the river basin planning, and all our existing science, technology, mathematics and practical experience in this field will be needed to achieve compliance with the water quality standards with regard to chemical substances and ecological status. Hydrological and biogeochemical cycling, in particular, and the resource conditions for the assembly of the plankton community must be considered comprehensively. Until quite recently the theoretical

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foundation for ecology was empirical rather than theoretical, ranging from deterministic to stochastic approaches, and hence there is no equivalent comprehensive biological foundation analogous to Newtonian mechanics or hydrodynamics that can be employed for the control of eutrophication and pollution in lakes and rivers. In addition, the determination, calibration and validation of prediction models is hampered by the overwhelming number of factors affecting the composition and activity of plankton assemblages and by the limited experimental and observational resources available. Hence the translation of scientific theories specific observations on river basin and mathematical approaches into forms which are useful for river basin planning is difficult. Prediction models are nevertheless considered useful for river basin management and are used to predict the behaviour of water quality with respect to changes in pollutant loads and hydrological conditions. They are therefore used to evaluate target pollutant loads and management actions which will achieve compliance with water quality standards. The target pollutant loads are then used to set up regulatory rules and to plan waste water treatment plants, agricultural practices and general land use.

Simple empirical water quality models are based on statistical methods which makes quantitative learning and prediction efficient. Early attempts were made in the 1970 to estimate statistical relationships in data from a large sample of lakes (Borsuk et al., 2001), and more complex mechanistic models structured in the 1970 according to the causal understanding and mathematical descriptions of processes prevailing at that time, sometimes accompanied by least-squares parameter estimates, approximate first order error analysis, Monte Carlo analysis or Kalman filtering. The error term in a model was usually neglected in the context of prediction (NRC, 2001). The lack of proper error estimates was compensated for by a comprehensive mathematical description of the process. Thus, the development of mechanistic models for water quality and hydrodynamics were seen to be interrelated.

The Water Framework Directive urges member states to quantify numerically the present and near-future maximum loads (i.e. target pollutant loads) to be permitted for pollutants, from point and non-point sources and from background sources, so that they will meet water quality standards with an adequate margin of safety (MOS). Due to the probabilistic and random nature of water quality parameters, a small MOS might result in non-attainment of the water quality goal, while a large MOS can be inefficient and costly (NRC, 2001). Therefore the MOS should account for the errors in the data and the model. Ideally, MOS represents the joint probability of possible errors in the estimated target load, load estimates and transcendence of the water quality standards (NRC, 2001). The problem is how to estimate model parameters and error variances of predictions realistically and determine how errors in these and in the inputs propagate through the model and result in error in the estimated target pollutant load.

Another problem is that approximate error estimation methods involving complex mechanistic water quality models and small-sized water quality samples are likely to result in unrealistic (Ascher and Overholt, 1983; NRC, 2001) and overly optimistic error estimates. This in turn will bias the MOS of the target pollutant loads and reduce the efficiency of river basin management.

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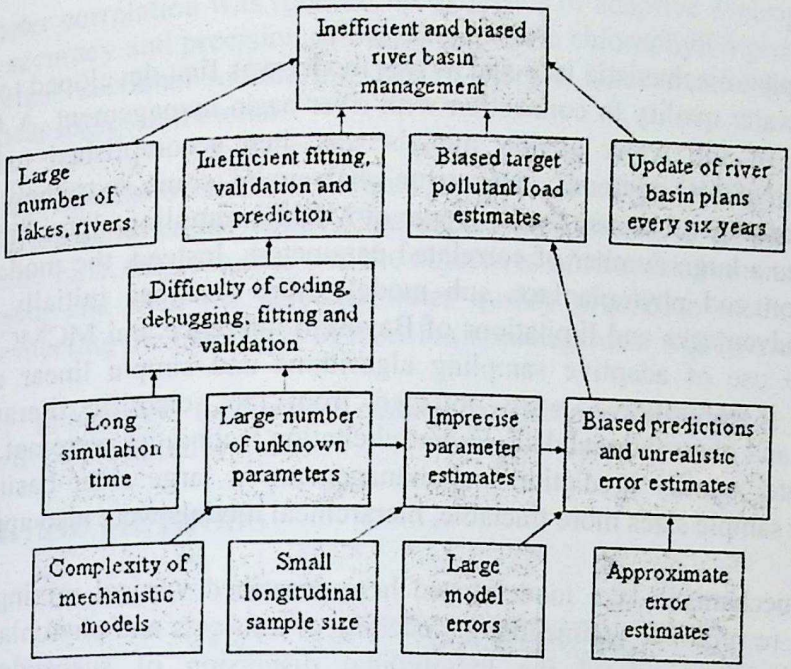

Figure 1: Outline of the problems involved in water quality prediction and their implications for river basin planning and management.

The coding, debugging, fitting and validation of complex mechanistic water quality models is difficult due to the long simulation time and the large number of unknown parameters, making water quality prediction and river basin management less efficient and more costly than is necessary for effective decision making (NRC, 2001).

Moreover, twenty per cent of the studied lake area is in a satisfactory or worse condition, which means that the number of lakes requiring pollutant load control amounts to hundreds and the updating of river basin plans every six years using complex water quality models will not be efficient or even feasible.

The general objective of this paper were to make the updating of water quality predictions, the accompanying error estimates and river basin plans every six years as efficiently and realistically as possible (Figure 1). It was aimed at using Bayesian inference, Markov chain Monte Carlo methods (MCMC), hierarchical models (HM) and model simplification. Bayesian inference and MCMC methods were to be used for synthesizing mechanistic modelling and statistical inference and facilitating realistic error estimation and the efficient updating of predictions in the light of the continuously accumulating monitoring data. A hierarchical modelling strategy (Gelman and Hill, 2006) was used to improve the accuracy and precision of lake specific the predictions.

The practical objectives were computational implementation of the methods, the derivation of relevant water quality data, application of these methods to real-world river

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basin management cases and the setting up of guidelines for applications to river basin management.

A complex mechanistic lake and a river model was first developed to facilitate the prediction of water quality in connection with river basin management. A full statistical error analysis of sub water quality models was then accomplished using Bayesian inference and MCMC methods. The error analysis of some extremely complicated models was postponed because the converge of MCMC sampling algorithms is slow if a model includes a large number of correlated parameters. Instead, the moderately simple lake respiration and phytoplankton sub models were analysed initially. This clearly revealed the advantages and limitations of Bayesian inference and MCMC methods and motivated the use of adaptive sampling algorithms and simple linear models. Prior distributions, if informative, were obtained from the scientific literature or from experimental and observational data. Expert elicitation techniques were not used here. To make the water quality prediction and management in large river basins with small observational sample sizes more tractable, hierarchical models were also applied.

The mechanistic lake models used here described vertical mixing, temperature stratification, respiration, sedimentation, leaching of nutrients and phytoplankton growth. The river model calculated the longitudinal dispersion of suspended solids and contaminated sediments. The models were formulated with partial and ordinary differential equations and integrated by numerical methods.

A hierarchical linear regression model (HLRM) (Gelman and Hill, 2006) was used to predict chlorophyll a in studied lakes. Hierarchical linear modelling (HLM), also known as multi-level analysis, is a more advanced form of multiple linear regression.

Multilevel analysis allows the variance in outcome variables to be analysed at multiple hierarchical levels, whereas in multiple linear regression all effects are modeled as occurring at a single level. Thus HLM is appropriate for use with nested data. In river basin management, data from lakes can be nested within lake types and ecoregions.

The errors in the mechanistic and hierarchical models are related to errors in the measurement of the x variables, in the model and in the model parameters (Box and Tiao, 1973; Clark, 2006). These were estimated using Bayesian inference and MCMC methods, which facilitate statistical learning and the updating of water quality predictions and river basin plans.

Bayesian inference methods and Markov chain Monte Carlo (MCMC) methods were used here to change the paradigm of water quality prediction and river basin management decision making from deterministic to statistical. Mechanistic river and lake models for the evaluation of target phosphorus loading and restoration dredging were developed.

This enabled the mechanistic water quality predictions to be better accommodated into river basin management. The slow convergence of the MCMC chains in the case of

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marked parameter correlation was speeded up by means of adaptive Metropolis Hastings methods. The accuracy and precision of the lake-specific chlorophyll a predictions based on extensive cross sectional monitoring data of studied lakes were enhanced using a hierarchical linear regression model.

The main results of the five original papers listed at the beginning of this publication will be summarized below. The papers are referred to in the text by their Roman numerals. First, the case data and the objectives of river basin management cases will be analysed, and then the selected water quality prediction methods and their capabilities for meeting the objectives of river basin management will be evaluated.

Finally, guidelines for water quality prediction in adaptive river basin management will be proposed.

2-MATERIAL AND METHODS

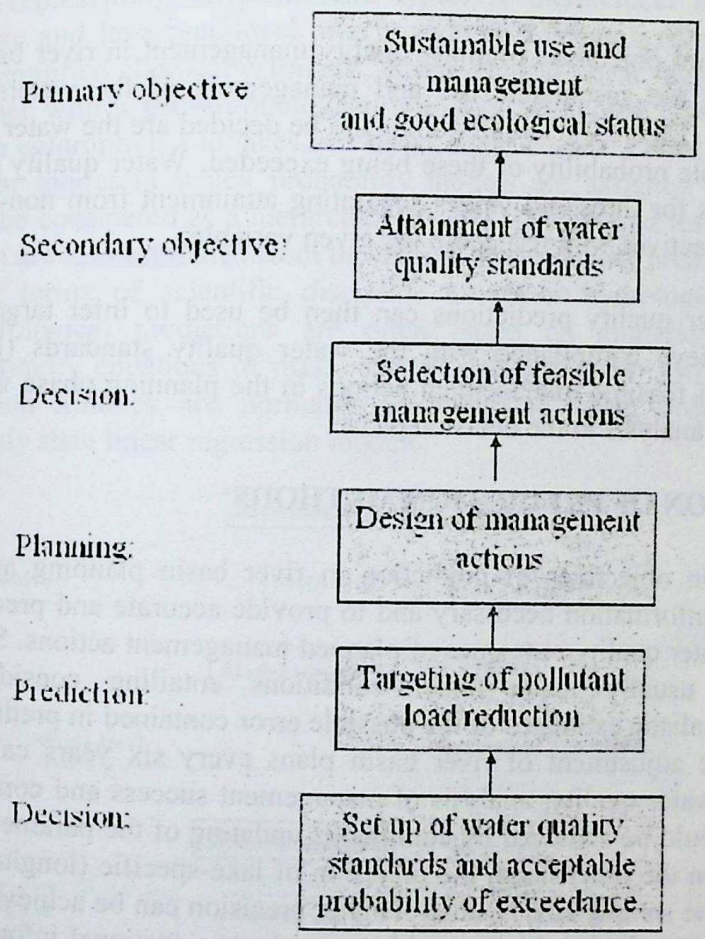

Figure 2: General objectives of water quality management in river basin planning.

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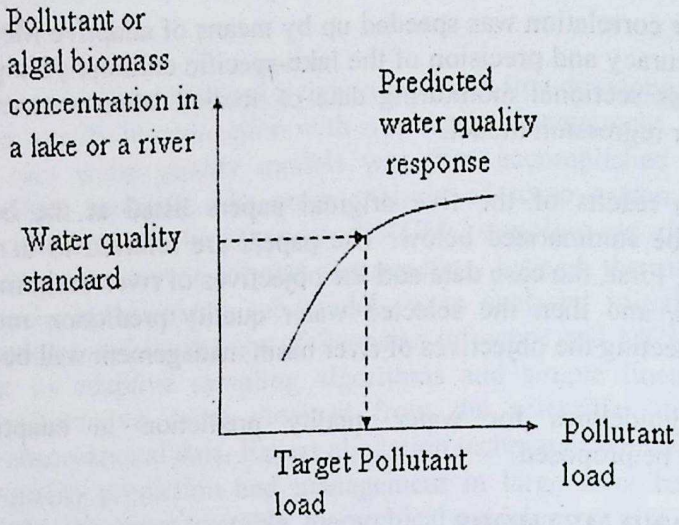

Figure 3: Inference of target pollutant loading using predicted water quality response.

The general objectives of water quality management in river basin planning and decision making are sustainable use and management of the waters and their good ecological status (Figure 2). The first things to be decided are the water quality standards and the acceptable probability of these being exceeded. Water quality standards include numerical values for threshold values separating attainment from non-attainment of the management objectives with respect to the given variables.

The water quality predictions can then be used to infer target pollutant loads which will achieve compliance with the water quality standards (Figure 3) and to generate a set of feasible management actions in the planning phase with a view to the cost and benefit analysis in the decision phase.

3- EVALUATION OF PREDICTION METHODS

The main objectives of prediction in river basin planning are to acquire and analyse all the information necessary and to provide accurate and precise predictions of the expected water quality outcomes of planned management actions. Since management decisions are usually made under conditions entailing considerable predictive uncertainties, realistic estimates of the possible error contained in predictions are needed. In addition, the adjustment of river basin plans every six years calls for continuous monitoring of water quality, analysis of management success and correction of failures. Ideally, this should be achieved by continuous updating of the parameters and predictive distributions. On the other hand, the precision of lake-specific (longitudinal) predictions will be low if the sample size is small. Higher precision can be achieved most efficiently using estimation methods which are able to pool cross-sectional information in order to make longitudinal inferences. The accomplishment of the above objectives are expected to promote efficient river basin planning and management.

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3.1 Classification of prediction methods

Water quality prediction methods can be classified by reference to several attributes, the most important among which are the modelling approach, the structure of the model and the scientific discipline concerned (Figure 4). According to this classification, the prediction approach can be either mechanistic, statistical or Bayesian, where a mechanistic approach relies on comprehensive process description using numerical integration of partial or ordinary differential equations, while statistical prediction is based on classical statistical point estimation, which is somewhat approximate if applied to mechanistic models. In contrast, a Bayesian approach can combine mechanistic process description and observational data resulting in a posterior predictive distribution, which is useful in river basin management (Box and Tiao, 1973; Clark, 2006).

Models are classified here in terms of their structure and that of the data used as either hierarchical or composed of a "single" level (Gelman and Hill, 2006). Classical "single" level estimates may be useless if fitted to a lake with a small sample size and misleading, in that they ignore variation between lakes and lake types if fitted to composite data representing different lake types. A hierarchical model allows the estimation of lake and lake type-level effects and can achieve a compromise between noisy and oversimplified classical estimates. A hierarchical linear regression model was used here together with a geomorphological typology of studied lakes to estimate the nutrient effect on chlorophyll a in lakes of varying sample sizes. For example, a linear or generalized linear model in which probability models are assigned to the regression coefficients can be considered as a hierarchical model. This second level has parameters of its own, which are also estimated from the data. A water quality prediction method can be classified in terms of scientific discipline as either hydrological, chemical or biological. Hydrological predictions are often based on numerical integration of complicated continuity equations of mass, energy and momentum, while chemical and biological reaction kinetics are normally approximated using ordinary differential equations or steady state linear regression models.

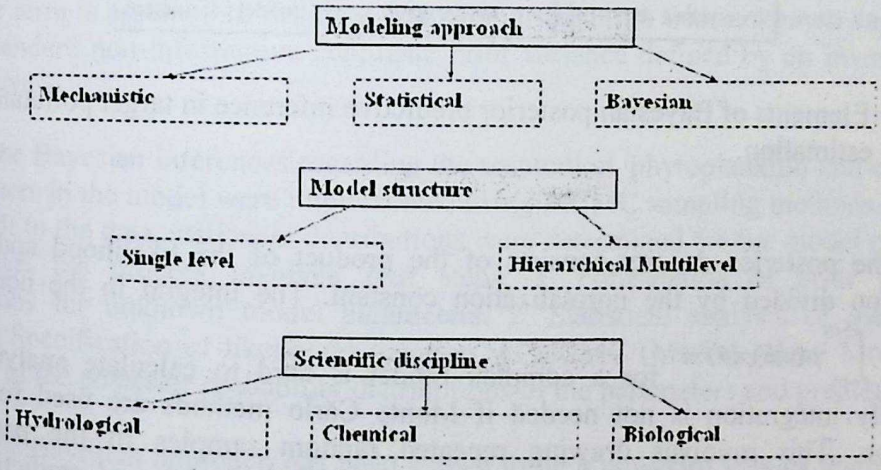

Figure 4: Classifiers of prediction methods.

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3.2. Bayesian inference using MCMC methods

A Bayesian approach facilitates continuous updating of parameters, error variances and predictions as new information accumulates (Figure 5). Bayesian methods do this formally as

$$\text{posterior} \propto \text{likelihood} \times \text{prior} \quad (1)$$

The likelihood ($p(y|\theta)$) and prior density $p(\theta)$ for a parameter enable calculation of the posterior density $p(\theta|y)$, the distribution of which for an unknown parameter θ is formulated as:

$$p(\theta|y) = \frac{p(y|\theta)p(\theta)}{p(y)} \quad (2)$$

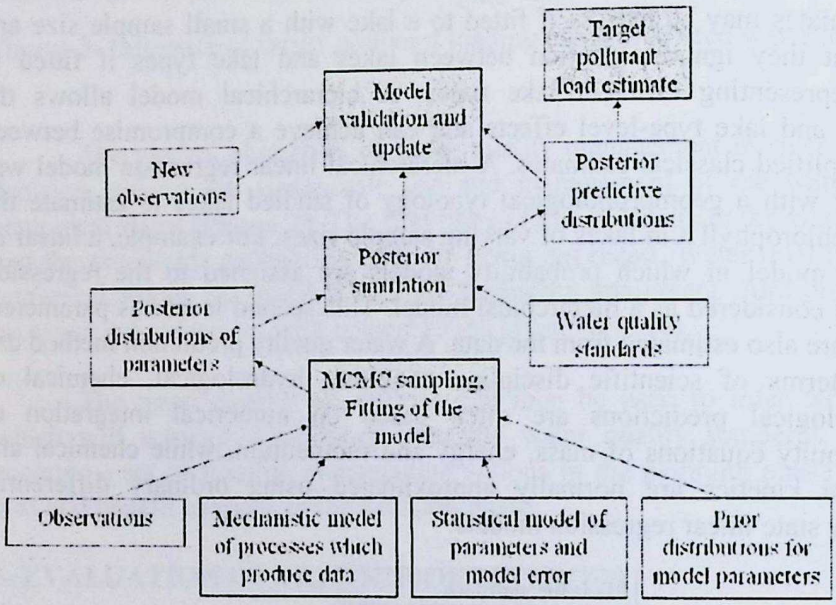

Figure 5: Elements of Bayesian posterior predictive inference in target pollutant load estimation.

The posterior density consists of the product of the likelihood and the prior distribution divided by the normalization constant. The integral in the normalization constant $\int_{-\infty}^{+\infty} p(y|\theta)p(\theta)d\theta$ for a complex model is hard to calculate analytically, but fortunately integration is not needed if Monte Carlo methods are used for posterior simulation. This involves drawing repeated random samples of the parameter or parameter vector. Several methods exist for posterior simulation and prediction, among which the Markov chain Monte Carlo (MCMC) method allows simulation of multivariate distributions and is usually implemented as a random walk through the parameter space. During the 'burn-in' period the Monte Carlo averages converge to the target distribution,

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after which samples of parameters are used to estimate the posterior distribution. Non-standard distributions are sampled here using Metropolis-Hastings (Clark, 2006) and Gibbs sampling (Clark, 2006).

3.2.1. Prior distributions

To fit the models to Bayesian methods, a prior distribution for the parameters needs to be specified. Since prior independence of the parameters was assumed, only a marginal density for each component of the parameter vector was assigned here. The strongest form of prior assumption is that a parameter is a fixed constant, e.g. as obtained from literature. Alternatively, a 'fixed' constant may be treated as a parameter with a narrow prior distribution. If no prior value is known or if we want the posterior value to depend solely on the observed data, a flat "non-informative" prior assumption is preferred, perhaps with a positivity constraint, as with many of the parameters in the present cases. Nevertheless, every new parameter increases the dimension of the vector to be sampled and increases the computational burden. Mainly Gaussian prior distributions with possible upper and lower limits for the values (e.g. positivity constraints) are used in the present work.

3.2.2. Model error

Since the models described the system on a non-transformed scale, they had to be transformed accordingly for the fitting procedure. The observational error was modelled as a Gaussian random variable. The errors in the lake respiration and chlorophyll a models were additive with respect to the modelled concentration, and the error term ϵ_i the phytoplankton model was additive with respect to the square root of the modelled concentrations:

$$\sqrt{y_i(t)} = \sqrt{\mu(x_i;\ \theta)} + \epsilon_i \quad (3)$$

where ϵ_i is the error term. The error term of the model contains all the unexplained factors, and may include several sources of errors other than pure observational error. The error term is assumed to follow a Gaussian distribution with unknown variance. We used a standard non-informative conjugate prior variance defined by an inverse gamma distribution.

The Bayesian inferences regarding the respiration, phytoplankton and chlorophyll a parameters in the model were implemented using MCMC sampling methods. Instead of a single fit to the data, statistical distributions were determined for the model parameters. In practice, the process involved four steps: 1. Formulation of prior probability distributions for unknown model parameters. 2. Statistical analysis of measurement errors. 3. Specification of likelihood function. 4. MCMC (Markov chain Monte Carlo) sampling of the posterior probability distributions of the parameters and predictions.

The Bayesian approach has been shown to be a powerful way of quantifying the uncertainties in the whole modelling procedure (Adams, 1998; Annan, 2001; Raiffa, Schlaifer, 2000). The MCMC computations and adaptive MCMC strategies used here are demonstrated and described in Haario et al. (2003). MCMC is popular in computational

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statistics at the moment (Gelman et al., 2005) and can be applied to a wide variety of modelling problems.

Although recent advances in MCMC computing and increasing CPU resources have made larger problems tractable, computational problems still arise on account of correlations between parameters. The limited availability of observational data and the structure of non-linear modelling equations may cause correlation between parameters, which can be reduced through better design of the experiments and reparametrization of the model. In situ monitoring does not favour orthogonal observational design for generating completely uncorrelated observations of independent variables, however, and adaptive MCMC methods have been developed as a remedy. Adaptive methods make the procedure statistically efficient and reduce the need for laborious hand tuning of the algorithm. In fact, they adapts the proposal distributions for the generation of new samples according to the Adaptive Metropolis algorithm (AM) instead of using a fixed proposal distribution. In addition, a number of different scales for the proposal distribution were used, employing the Delayed Rejection (DR) method.

The number of iterations that the Monte Carlo averages need to converge to the true posterior distribution is called the burn-in period. Samples obtained after the burn-in were saved for statistical inference of the posterior distribution. To ensure convergence and to estimate the lake respiration and phytoplankton dynamics, several runs were carried out sequentially, each sequence starting from the values of the previous chain, and convergence was diagnosed visually from 1d and 2d plots of the chains. In contrast, the length of the burn-in period for the hierarchical regression model, multiple MCMC chains of different length were run and $\hat{R}$ statistics (Gelman and Rubin, 1992) were calculated for each chain. If $\hat{R} \approx 1$ the burn-in period was deemed adequate.

Where Bayesian inference and MCMC methods were used for model fitting, the water quality responses to planned pollutant load reductions and management actions were predicted using posterior simulation methods. Predictions were calculated repeatedly with sampled parameter values and error variances from their posterior distribution and with relevant environmental control variables derived from their observed distributions. The simulated predictive distributions revealed prediction errors realistically and rationalized river basin management accordingly.

3.3. Model validation

Prediction with mechanistic models was mainly based on a theoretical understanding of the underlying mechanism and the consequent causal relationships. Runs with data located outside the range of variation of the calibration data were used to confirm the model and to reveal structural errors and limitations in it.

Validation in an empirical modelling approach is clearly related to the scientific learning process (Clark, 2006), where a tentative model suggests an experiment or observational data gathering process and an appropriate analysis of the data can lead to a new experimental or observational design (Box and Tiao, 1973). The alternation between the model and experiment is carried out by means of experimental design and data

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analysis. The efficiency of the underlying statistical learning process depends on the appropriateness and power of the design and analysis methods employed. In Bayesian analysis, a prior distribution is combined with the data to calculate the posterior distribution, from which inferences regarding the parameters are to be made.

Comprehensive validation of mechanistic models is a luxury that is seldom achieved in water quality management, due to limitations caused by sparse data and the complicated model structure. Scientific learning using statistical analysis methods involves a continuous iterative approach in which management decisions are conditional on the validity of the tentative model and the available information. River basin management decisions thus have to be modified alongside this iterative learning process and model criticism.

The validation of the mechanistic water quality model for Lake was hampered by the small observational water quality sample size, which meant that the data could not be separated out into calibration and validation sets. By contrast, one-year data on dioxin concentrations in settling suspended solids were available for validation of the transport model for the River Kymi. The respiration model for Lake and the chlorophyll a model for the Studied lakes were not validated, either, but the phytoplankton model for Lake was validated with data from 5 additional years. The residual normality of the respiration, phytoplankton and chlorophyll a models was investigated through a graphical display of the predictive distributions and observations. Sensitivities to prior distributions and model structure were not studied.

To facilitate comparison of the hierarchical linear model with non-hierarchical dummy variable models, we calculated the deviance information criterion (DIC), a Bayesian measure of model complexity and fit (Spiegelhalter et al., 2002). DIC is the sum of the posterior mean deviance $D(\theta)$, a Bayesian measure of fit or "adequacy", and a complexity measure pD (effective number of parameters), which corresponds to the trace of the product of Fisher's information and the posterior covariance.

4-ATTAINMENT OF PREDICTION OBJECTIVES

The objectives of prediction differed greatly between the cases studied here. The aim at first was to predict water quality responses to reductions in pollutant loading and to plan management actions as efficiently and realistically as possible. Later on, Bayesian inference and MCMC methods were adopted for estimating prediction errors without linearization typical of classical least square methods. The small size of the water quality samples in the lake monitoring data available suggested that complex mechanistic models would prove inefficient for practical river basin management purpose despite the ease of applying MCMC methods, and therefore Bayesian inference and MCMC methods were applied only to the water quality sub models at first. Later on, the nutrient model was fitted to data from Lake by Bayesian methods, and was combined with the phytoplankton model to predict Cyanobacteria biomass as a function of nutrient load.

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A hierarchical chlorophyll a model for the studied lakes was developed in order to meet the need for a simple and efficient prediction method for use in river basin management.

The applications of the prediction methods developed here will be evaluated in the following paragraphs on the basis of the case studies and the criteria for predictive scientific theories as summed up by Peters (1991). The selected criteria highlight the efficiency and predictive power of a scientific theory and reject exhaustive causal explanation of the natural processes involved as an objective for useful scientific.

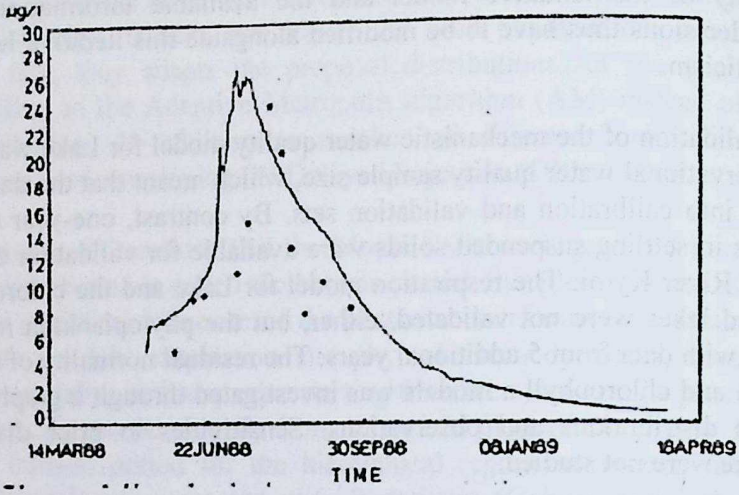

Figure 6: Observed and simulated chlorophyll a concentrations [μg l−1]

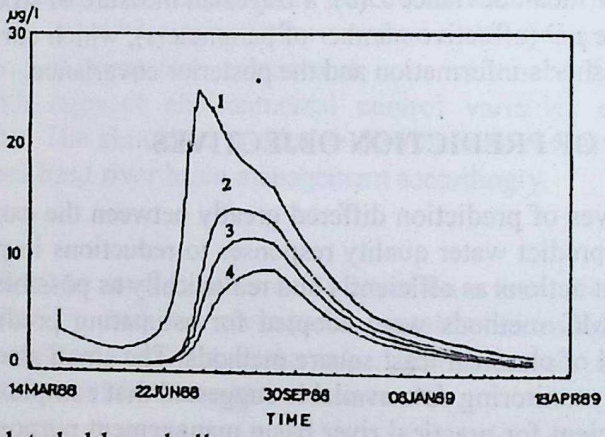

Figure 7: Calculated chlorophyll a concentration [μg l−1] with loading levels: 1

The simulated temperatures and ice thicknesses agreed well with the values observed in 1987 - 1988, but the modelled temperature stratification in late August was ten days longer than observed and a mean error of 1.5 days arose in the ice duration. Of the water quality model parameters, the BOD decay rate, sediment oxygen demand, net

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sedimentation of phosphorus, phosphorus release from the sediment under anaerobic conditions, algal growth, algal respiration and rate of chlorophyll a sedimentation were calibrated with one year of observed data (May 15, 1988 - April 30, 1989). Parameters were fitted to predict average chlorophyll a, dissolved oxygen and total phosphorus concentrations. Calibration was carried out graphically without mathematical parameter optimization or error analysis methods.

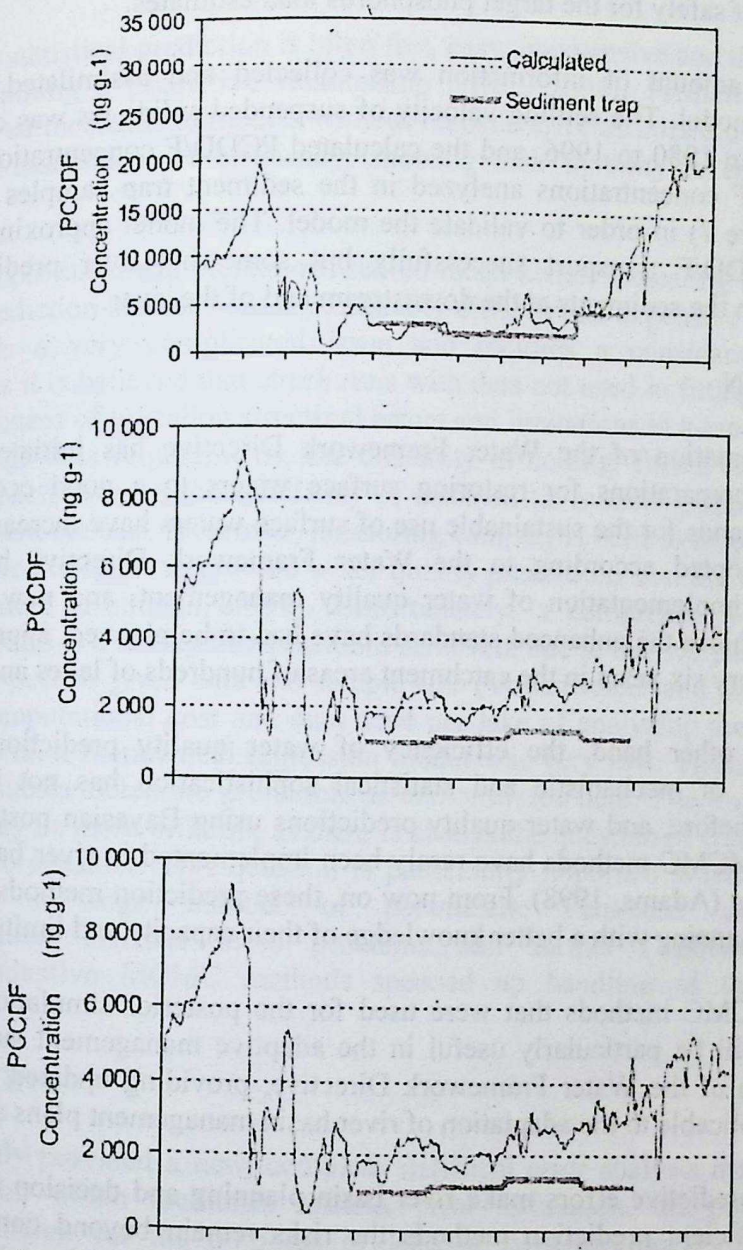

Figure 8: Model verification. Calculated PCDD/F concentrations in suspended solids in the river water, and concentrations observed in sediment traps in 1997.

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The study of the effects of the reduction in non-point source phosphorus loading on chlorophyll a was based on the hydrological, meteorological and phosphorus loading data collected from April 1, 1988 to March 31, 1989. Since chlorophyll a as predicted with scenario number 4 (the best available protection measures, 44 % reduction) (Fig. 7) was below the standard (10 ìg l.1), the respective load (0.19 gPm.2 a.1) was selected as a target nutrient load for lake management. As the model error and parameter and predictive distributions were not estimated, and the long-term variation in control variables was not measured or used in the simulation, the computed effects ignored natural variation and predictive uncertainty. Hence, it is not possible to calculate an explicit margin of safety for the target phosphorus load estimates.

A large amount of information was collected and assimilated into the 1-D hydraulic river model. The settling velocity of suspended solids ws was calibrated with observations from 1980 to 1996, and the calculated PCDD/F concentrations in the river and the PCDD/F concentrations analyzed in the sediment trap samples in 1997 were compared (Figure 7) in order to validate the model. The model approximated the main features of PCDD/F transport successfully but somewhat over predicted PCDD/F concentrations in the sediments at the downstream end of the river.

5- DISCUSSION

Implementation of the Water Framework Directive has initiated unparalleled administrative preparations for restoring surface waters to a good ecological status. Legislative demands for the sustainable use of surface waters have increased, river basin planning as adopted according to the Water Framework Directive has altered the objectives and implementation of water quality management, and new pollutant load controls that achieve the enhanced standards have had to be planned, approved, executed and updated every six years in the catchment areas of hundreds of lakes and rivers.

On the other hand, the efficiency of water quality predictions representing different levels of mechanistic and statistical sophistication has not been examined systematically before, and water quality predictions using Bayesian posterior predictive inference and MCMC methods have rarely been implemented in river basin planning or decision making (Adams, 1998). From now on, these prediction methods can be applied to river basin planning with a better knowledge of their capacity and limits.

The MCMC methods that were used for the posterior simulation of predictive distributions will be particularly useful in the adaptive management suggested for the implementation of the Water Framework Directive, providing updated predictions that are directly applicable to the adaptation of river basin management plans and decisions.

Large predictive errors make river basin planning and decision making difficult for without efficient prediction methods the risks remain beyond control and wrong decisions may be made (NRC, 2001). The Bayesian posterior predictive inference methods tested here enabled the prediction errors to be estimated more realistically than with classical least-square methods and first-order error analysis.

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Longitudinal (lake-specific) water quality predictions and river basin management decisions are often based on either cross-sectional (observations from many lakes) or longitudinal (observations from one lake) monitoring data, with the result that they tend to be inaccurate or imprecise (wide credible intervals). Bayesian posterior predictive inference and hierarchical linear regression models were used here as a remedy, to facilitate the pooling of cross-sectional information and to make the lake-specific predictions more accurate and precise.

Simple statistical prediction is often fast, easy, inexpensive and the most effective way of determining a predictive relationship (NRC, 2001). Predictions made using overparametrized mechanistic models without realistic error estimates did not score well in the present assessment of efficiency, showing their inability to ensure success in management.

The simple statistical predictions scored much better, indicating that complicated mechanistic prediction methods are unreasonably difficult and expensive to apply. Model confirmation is a very complicated issue and requires a considerable number of observations, as it is believed that check runs with data not used in fitting the model will offer the best means of revealing structural errors and limitations in a mechanistic model. Besides the huge data requirements, the difficulty of coding, fitting and validation of mechanistic models reduces the efficiency of mechanistic modeling approach in a river basin management context. Moreover, measuring campaigns need to be comprehensively and well designed in order to provide water quality predictions that are relevant in river basin management (Kettunen, 1993). Unfortunately, a comprehensive validation of mechanistic models is a luxury that is seldom achieved, due to the overparametrization of models with respect to given data and sample size (Vollenweider and Kerkes, 1980). In contrast, the computational cost and data need per lake of analyzing the two thousands Studied lakes with a hierarchical regression model was very low. Thus, simple models that are easily substantiated are preferable as demonstrated here. The implementation of MCMC runs may be more difficult, as there is always the question of convergence of the MCMC chain to consider. This question is particularly important when dealing with a model having a large number of parameters. Parameter correlation and overparametrization increase these problems still further (Vollenweider, 1976). Nevertheless, adaptive MCMC methods speeded up handling of the convergence considerably.

6-CONCLUSIONS

This study provided a new, complete statistical error analysis method for water quality prediction which facilitates realistic error estimation, the pooling of cross sectional information for the purposes of lake or river-specific prediction and the updating of predictions. As a result, river basin planning can be based on efficient, flexible and realistic prediction methods. The main findings were:

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- The realistic estimation of error in predictions is a prerequisite for effective river basin management.
- Realistic error estimates for mechanistic water quality predictions can be obtained using Bayesian posterior predictive inference and MCMC sampling methods.
- The accuracy and precision of water quality prediction can be improved using Bayesian inference and a hierarchical model which pools cross-sectional information for lake-specific predictions.
- Bayesian inference and MCMC methods are no more difficult to implement than classical statistical methods. Even models with large numbers of correlated parameters can be fitted using modern computational methods.
- Simple empirical models are efficient for river basin management, indicating that complex mechanistic models are unreasonably difficult and expensive to apply. Guidelines were set up for water quality monitoring, prediction and river basin management in order to cope with a large number of lakes and rivers using relatively small sample sizes. River basin monitoring should be designed statistically using the prediction error of the water quality model as an objective function. This will maximize the information value of water quality observations and minimize the prediction error.
- In addition, national networks for monitoring diffuse pollutant loads should be established instantly in order to meet the pressing needs of river basin management. Without determined monitoring efforts, water quality predictions will be biased and river basin management may fail to maintain the sustainable use of water resources. Prediction is ideally implemented using Bayesian inference, MCMC methods and a simple hierarchical model. The complexity of existing mechanistic water quality models should be simplified in order to reduce their computational costs and large data requirements.
- The potential of prediction has not yet been fully realized in river basin management.

For example, a prediction model can be used for the statistical design of observations in order to maximize their information value (Winkler, 2003). Disregard of this possibility has resulted in inefficient observations and imprecise predictions. This feature will be even more important for the updating of river basin plans every six years. The continuous updating of predictions and river basin plans along with continuous monitoring constitutes an adaptive management procedure that facilitates continuous learning and correction of the courses of action adopted on the way to achieving agreed water quality goals. The statistical design of measurement protocols should be integrated into water quality prediction and management in order to galvanize the development of adaptive management strategies. The Bayesian posterior predictive inference methods introduced in this study provide new possibilities for this kind of development – not least for the statistical updating procedure, which is an intrinsic part of Bayesian inference. The use of simulated response surfaces should be developed further to allow response surface methods to be applied to river basin planning and to make good use of past and future monitoring data. The use of MCMC methods in the present instance was limited to water quality models of a single water body, but in order to enhance the utility of

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predictions for river basin management, their application should now be extended to cover entire river basins and a wider range of restoration techniques.

The inferential statistics developed in this study help in drawing conclusions and making predictions on the basis of limited information, but statistical decision making can go further. In addition to prediction, it can helps in revising management actions and monitoring programmes and in choosing among a number of alternative forms of river basin management. Its full potential (Reckhow, Chapra, 1983) for river basin management remains to be explored.

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MORPHOMETRIC ANALYSIS FOR PEDDAVAGU A TRIBUTARY OF KRISHNA RIVER, NALGONDA DIST., A.P., INDIA

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ABSTRACT

The analysis of drainage morphometry is usually a prerequisite to the assessment of hydrological characteristics of surface water basin. The basin morphometric parameters such as linear and aerial aspects of the river basin were determined and computed. The study performed manual and computerized delineation and drainage sampling, which enables applying detailed morphological measures. The measurement of drainage parameters provides the Hydrologist & Geomorphologist with the useful tool for numerical measure of landscape dissection & runoff potential. Evaluation of the characteristics of the drainage network of a basin using quantitative morphometric analysis can give information about the hydrological nature of the rocks exposed within the drainage basin. A drainage map of a basin provides a reliable index of the permeability of the rocks and also gives an indication of the yield of the basin. The yield of a basin is the flow per unit area and normally includes surface-water flows unless mentioned otherwise. Normally, such an analysis of drainage basins involves the evaluation of drainage parameters such as bifurcation ratio, length ratio, drainage density, constant of channel maintenance, length of overland flow and stream frequency. Hydrogeological observations, integrated with drainage analysis, provides useful clues on topography and underlying geological structures.

The drainage map of the Peddavagu watershed, prepared from the survey of India topographic sheet number 56 0/8/SW. The Peddavagu basin was analysed for stream-order analysis, basin length, stream frequency, bifurcation ratio (Rb), stream length ratio (R1), drainage density (Dd), constant of channel maintenance (1/Dd), lengh of over land flow (Lg) and stream frequency (F). Dimensionless factors such as Form factor (Ff), Elongation Ration (Re), Circulatory ratio (Rc). Measures involves height or Relief, Relief ratios and slope.

Keywords: Morphometry, River basin, Drainage basin, Linear aspects, Stream order analysis, Dainage analysis.

INTRODUCTION

Drainage basins or basins should be the study area for the better understanding of the hydrologic system. The optimal and sustainable development of the resource is prerequisite so that it is assessed rationally to avoid any future problems regarding its

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qualitative and quantitative availability. About 70% of population in India is dependent on agriculture, directly or indirectly. India has diverse geographical features and varied climates. It has 14 major basins through which drain numerous rivers, while rivers in the southern India are rainfed, with little perennial water. Accordingly, the importance of water has been recognized and greater emphasis is being laid on its economic use and better management. The basin morphometric characteristics of the various basins have been studied by many scientists using conventional (Horton, 1945; Smith, 1950; Strahler,1952) and remote sensing and GIS methods (Krishnamurthy and Srinivas, 1995; Srivastava and Mitra, 1995; Agarwal, 1998; Biswas et al., 1999; Narendra and Nageswara Rao, 2006). The fastly emerging spatial information technology (SIT) viz. remote sensing, GIS, and GPS has effective tools to overcome most of the problems of land and water resources planning and management on the account of usage of conventional methods of data process.

The present study area, Upper part of Krishna river basin, a part of the Peninsular India region is drained for a variety of agricultural fields, industrial purposes and also major source for the water supply to local villages. The main objective of this study is to compute basin morphmetric characteristics for various parameters.

The Peddavagu river basin covers an area 2.6 sqkm in the survey of India toposheet numbers 56 0/8/SW on a scale of 1:25,000.

Physiography of the study area:

The site area is on a top level surface of a hilly terrain at an altitude of about 439m above mean sea level (Map No.2). The southern boundary follows the path at contour elevation is about 340 msl and at 1 km to the south from site hilly terrain at an altitude of about 365m above mean sea level.

The area is undulating with two lineaments at NW-SE directions. The area is generally Northwest- Southeast low ground almost diagonally divides the area, slopes towards south. The drainage course flowing towards northwest to southeast and northeast to southwest.

The drainage is dentritic to sub-dentritic and courses are of first order and are having well defined courses traversing the discontinuous and scattered cultivated agricultural fields.

The approximate difference in land elevation between the highest and lowest points is about 27 m.

MATERIALS AND METHODS

The morphometric analysis of the Peddavagu river basin was based on published topographical Map on a 1:25,000 scale. The quantitative analysis of the morphometric characteristics of the basin include stream orders. Stream numbers, stream lengths, bifurcation ratios, basin circularity, drainage density, drainage frequency, drainage texture, relief ratio etc., which determines the geomorphic stage of development of the area on the basis of hypsometric integrals. The drainage network of the basin is analysed as per the laws of Horton (1945) and stream ordering is made after Strahler (1964).

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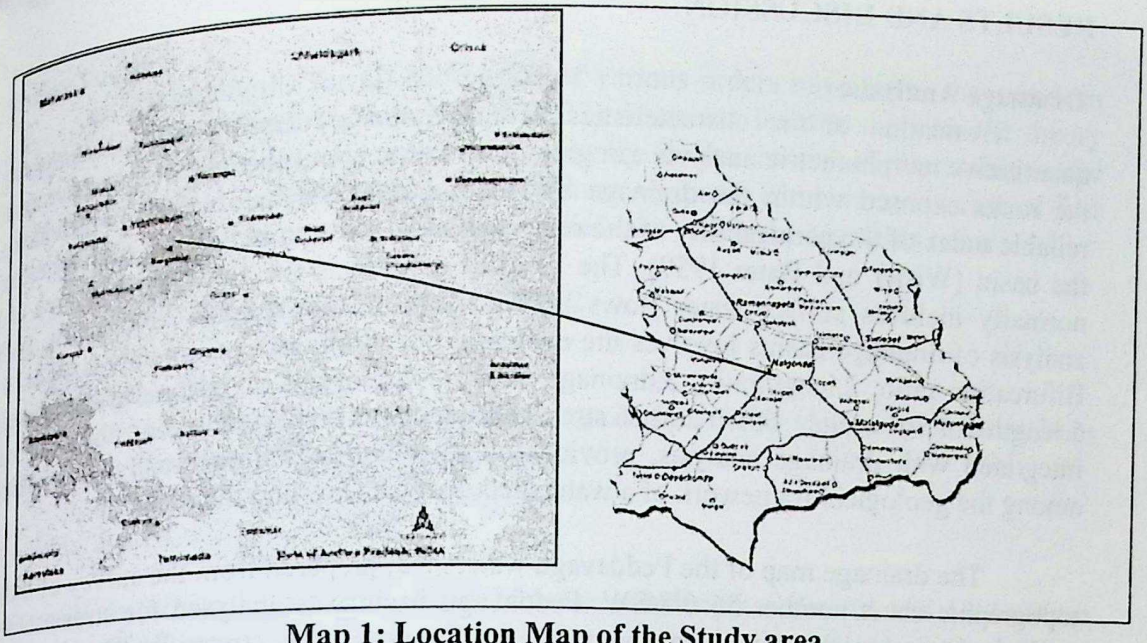
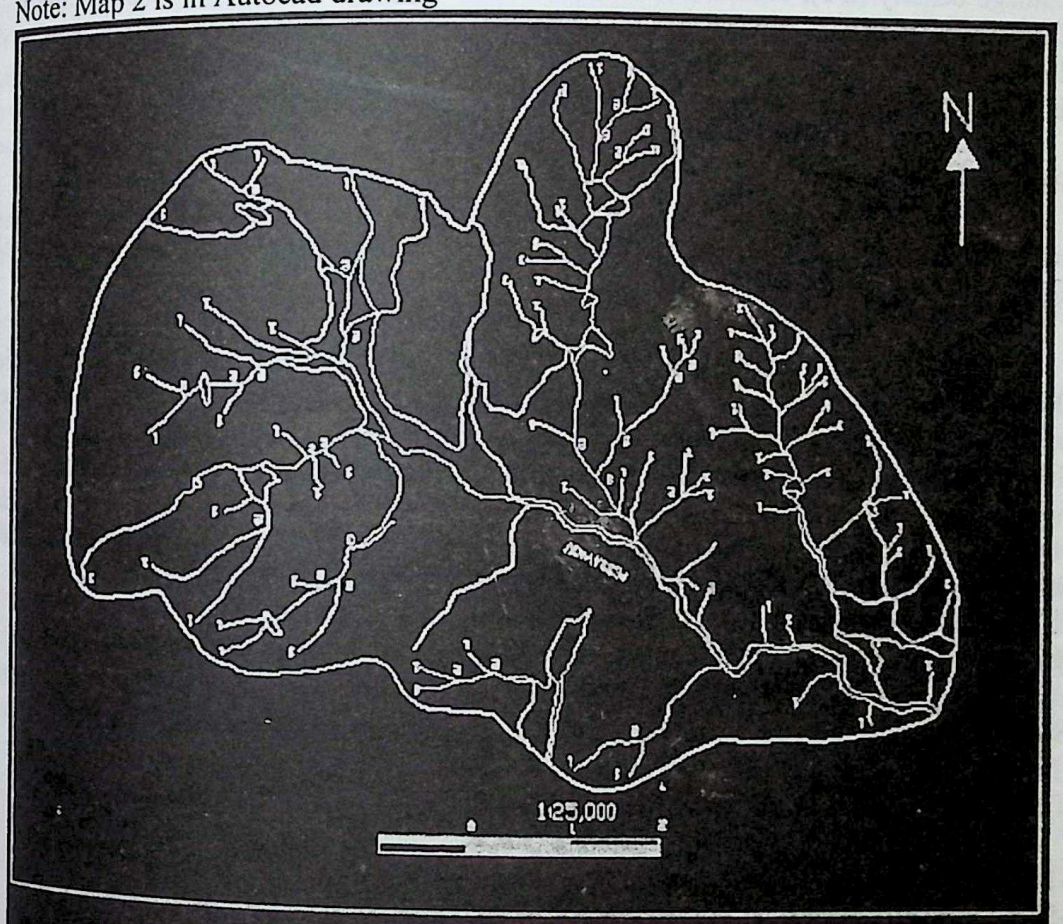


Map 1: Location Map of the Study area

Note: Map 2 is in Autocad drawing



Map 2: Peddavagu drainage basin

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RESULTS AND DISCUSSION

Drainage Analysis:

Evaluation of the characteristics of the drainage network of a basin using quantitative morphometric analysis can give information about the hydrological nature of the rocks exposed within the drainage basin. A drainage map of a basin provides a reliable index of the permeability of the rocks and also gives an indication of the yield of the basin (Wisler and Bater 1959). The yield of a basin is the flow per unit area and normally includes surface-water flows unless mentioned otherwise. Normally, such analysis of drainage basins involves the evaluation of drainage parameters such as 1. Bifurcation ratio, 2.lengthratio, 3.drainage density, 4.constant of channel maintenance, 5.length of overland flow and 6.stream frequency.Hydrogeological observations, integrated with drainage analysis, provides useful clues regarding broad relationships among the geological framework of a watershed, surface flow and the recharge.

The drainage map of the Peddavagu watershed, prepared from the survey of India topographic sheet number 56 0/8/SW. Peddavagu basin was analysed for stream-order analysis, basin length, stream frequency, bifurcation ratio (Rb), stream length ratio (Rl), drainage density (Dd), constant of channel maintenance (1/Dd), lengh of over land flow (Lg) and stream frequency (F). Dimensionless factors such as Form factor (Ff), Elongation ratio (Re), Circulatory ratio (Rc). Measures involves height are Relief, Relief ratios and slope .

Stream-order Analysis:

The advantage of ordering streams is that the stream order is a dimensionless number and hence can be used for the comparison of geometry of drainage network on different linear scales.

The study area encompasses a drainage basin, a part of the Peddavagu river, which flows through the Panagal. The basin drainage network was classified into orders according to the number of bifurcations using the method given by Strahler (1952). In this method, the smallest finger-tip tributaries are designated as first-order stream and two first-order streams unite to form a second-order stream; when two second-order streams join together a third order-stream is formed, and so on. The trunk or main stream through which all the discharge of water is carried is the stream of the highest order.

Stream order:

The streams of the Peddavagu river basin have been ranked according to the Strahler's (1964). Stream ordering system and the number of streams of each segment (Nu) of the order (U). The details of the order analysis of the Peddavagu river basin are Total number of orders present in Peddavagu river basin are three;

-The First-order streams are of 83 in number
-Second- order streams are of 28 in number
-Third-order streams are of 3 in number

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Stream length :

The steam lengths for all sub-basins of various orders have been measured on topographical maps. Horton's law(Horton 1932) of stream lengths supports the theory that geometrical similarity is preserved generally in the basins of increasing order (Strahler 1964). It is clear that the length of stream segments is maximum in case of first order streams. This is due to the variation in relief over which the segments occur.

Total length of the stream = 262.2

Stream length ratio:

The stream length ratios of the drainage basin of the study region have been calculated by applying the following formula

RL = Lu / Lu – 1

Where RL = Stream length ratio, Lu = Mean stream length order 'u' and Lu-1=Mean stream length of segments of the next lower order.

It is noticed that the RL between successive stream orders of the basins vary due to differences in slope and topographic conditions (Sudheer 1986; Sreedevi 1999). The RL has an important relationship with the surface flow discharge and erosional stage of the basin.

First order stream length
1+2+3/ ∑ 1 order=262.2/216.51=1.21

Second order stream length
∑ 1+2+3/ ∑ 2 =262.2/33.19=7.89

Third order stream length
∑ 1+ 2+3/ ∑ 3=262.2/12.5=20.9

Basin length (L):

Basin length (L) has been given different meanings by different workers (Schumm 1963;Gregory and Walling 1973). According to Gregory and Walling (1973), the L is the longest length of the basin, from the catchment to the point of confluence. The peddavagu river meets at the point of confluence in the extreme eastern part of the study area. The length of the Peddavagu River basin is 11Km .

44 X 250m
= 11000 m
L= 11 Km
262.2 /10,000 = 0.02

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Bifurcation Ratio (Rb):

In a sub-dendritic to dendritic drainage pattern, typical of the Archean province, the number of streams of any given order is higher than the number of streams of the next higher order. The ratio of the number of streams of given order to the number of streams of the next higher order, called the bifurcation ratio (Rb), reflects the complexity and degree of dissection of a drainage basin.

A bifurcation ratio greater than 5 indicates structurally controlled development of the drainage network (Strahler 1952). Rb=Nu/Nu+1

First order : 83/28+1=83/29=2.8
Second order : 28/3+1=28/4=7
Third order : 3
Total Streams : 114/83+1=1.35

If the value is less than 5. The geologic structure doesn't dominant the effect the watershed:114/28+1=3.93
Mature topography : 114/3+1=28.5. If it is >20 indicate.

Drainage Densit y (Dd) :

The drainage density is an indicator of the linear scale of landform elements in a stream-eroded topography (Horton 1945). It is the ratio of the total stream length of all orders within a basin to the area of the basin. It is indicative of the closeness of spacing of the streams and also the texture of the drainage basin. Basin has an average drainage density of 2.6 Km and is indicative of a medium- textured drainage basin.

Stream frequency (Fs):

The stream frequency (Fs) of a basin may be defined as the ratio between the total number of segments cumulated for all orders within a basin and the basin area (Horton 1945):

$$Fs = \sum Nu / A$$

Where $\sum Nu$ = Total number of stream segments of all orders and A = Total area of the basin.

The Fs of the whole basin is $0.01 km^2$. the development of the stream segments in the basin area is more or less affected by rainfall and temperature.

$$262.2 / 2.6 = 100.8 km/km^2$$
$$= 0.01 km/km^2$$

Length of overland flow :(Lg)

The length of overland flow is the length of stream flow paths, projected to the horizontal from the point of drainage divide to a point on the adjacent stream channel. The average length of overland flow is equal to half the reciprocal of the average drainage density (1/[2Dd]). The length of overland flow averages the down slope flow paths, from the drainage divide to the nearest channel. The length of overland flow also

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points to the efficiency of the drainage in the basin. The length of overland flow indicates longer flow paths and thus, gentler slopes. The values of length of overland flow for the third-order basins. Pointing to gentler slopes and longer flow paths for the basin shows that some of the basins have higher values than the average value for the third-order Panagal basin. (Table: 1)

1st order stream = 0.006
2nd order stream = 0.05
3rd order stream – 0.10

Table1: Indicate parameter of Drainage Analysis

Order of basin	No. of streams(N)	total length of the streams	Basin area (Km^2)	Drainage density Dd=L/A	Constant channel C=1/Dd	Length of over land flow Lg=1/2Dd
1	83	216.51	2.6	210.9/2.6=81.1	0.012	0.006
2	28	33.19	2.6	33.19/2.6=9.21	0.10	0.05
3	3	12.5	2.6	12.5/2.6=4.80	0.20	0.10

Dimensionless factors:

Elongation ratio (Re):

Elongation ratio (Re) is the ratio between the diameter of a circle of the same area as the basin and the maximum basin length. The Re is calculated by using the following formula:

$Re = 2A / \pi / L$

Where Re is the elongation ratio, 2 is constant, A = area and L is the maximum length of the basin.

The Re of the Peddavagu river basin is 0.15, these ratios indicate extremely elongated sub-basins. The variations of the elongated shapes of the basins are due to the guiding effect of thrusting and faulting in the basin.

$Re=2A/\pi/L$
$=2x\ 2.6/\pi/11$
$=2 \times 2.6/3.14/11$
$=0.15$

Circularity ratio (Rc):

The circularity ratio (Rc) has been used as a quantitative measure and is expressed as the ratio of basin are (Au) to the area of a circle (Ac) having the same

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perimeter as the basin (Miller 1953; Strahler 1964). It is affected by the lithological character of the basin and is expressed as: $Rc = 4 \quad A/P^2$. Where Rc is the basin circularity, 'P' is basin perimeter, '4' is constant and 'A' is the area of the basin.

The ratio is more influenced by length, Frequency (Fs),and gradient of streams of various orders rather than slope conditions and drainage pattern of the basin. It is a significant ratio, which indicates the dendritic stage of a basin. Its low, medium and high values are indicative of the youth, mature and old stages of the life cycle of the tributary basins. The Rc of the Peddavagu river basin is 0.15. The high value of the ratio is more influenced by length, frequency (Fs), and gradient of streams of various orders besides slope conditions and drainage pattern of the basin. it is a significant ratio, which indicates the dentritic stage of a basin. Its low, medium and high values are indicative of circularity ratio for sub-basins significance a late topographical maturity stage and the other sub-basins reveal and an early topographical mature stage. This anomaly is due to diversity of slope, relief and structural conditions prevailing in this basin.

4 x 3.14 x 2.6 / (0.0124)

Rc = 2633.5 / 10,000 = 0.26

Drainage texture :

The drainage texture (T) depends upon a natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development (Smith 1950). The soft or weak rocks unprotected by vegetation produce a fine texture, spare vegetation of arid climate causes a finer texture than those developed on similar rocks in a humid climate. The texture of a rock is commonly dependent upon vegetation type and climate (Dornkamp and King 1971). In simple terms T is the product of Dd and Fs

T = Dd x Fs

T = (81.1+9.21+4.80)*(100.8)

=9587.088

=9.5 fine texture.

Relief:

Basin relief is an important factor in understanding the denudational characters of the basin. Relief is the difference between maximum and minimum elevation of basin. The maximum height of the Peggavagu Basin is 220m to 190m. Therefore, the relief of the basin is 30.

Relief ratio

According to Schumm (1963) the relief ratio is the dimensionless height-length ratio equal to the tangent of the angle formed by two planes intersecting at the mouth of the basin, one representing the horizontal, the other passing through the highest point of the basin. The relief ratio is calculated by the following formula:

Relief ratio = H – h / L where H = highest elevation of the basin, h = lowest elevation in the basin and L = longest axis of the basin.

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The relief ratio of the Peddavagu river basin is 0.51. Generally the relief ratios of the basin as well as the sub-basins are low which are characteristic features of less resistant rocks of the area

H – h / L = 212-190 / 11 = 22 / 11000
=0.51 High resistant rocks

Slope: Slope analysis is an important parameter in geomorphic studies. The slope elements, in turn, are controlled by the climato morphogenic processes in the area underlying the rocks of varying resistance. An understanding of slope distribution is essential, as a slope map provides data for planning, settlement, mechanization of agriculture, reforestation, deforestation, planning of engineering structures, morpho conservation practices, etc. Though various methods are used to carry-out the slope analysis, average slope method was employed in this study using topographic maps on a scale of 1:25,000. The Peddavagu River basin area slope varies from 212° to 183°. A high degree of slope is noticed in the western and southern parts of the basin, mostly occupied by the granite and basic intrusives. Shale and limestone formations are characterized by low slope areas showing less than 2 in the remaining part of the basin.

H – h
= 212 – 183 = 29 m.

CONCLUSIONS

The Drainage morphometric analysis of Peddavagu river basin reveals the nature of subsurface strata is permeable. This is characteristic feature of coarse drainage as drainage density value less than '5'. Such type of drainage density shows good potential for construction of artificial recharge structures. The bifurcation ratio is 28.5 which indicate mature topography and dominate by the geologic structures. The mean Rb indicates that the drainage pattern is influenced by geological structures.

The Peddavagu river basin varies from 220m to 190m. A high degree of slope is noticed in Northwest of basin mostly occupied by basic intrusives and quartz veins. The quantitative aspects of morphometric characteristics of Peddavagu river basin reveals almost homegenous climate and heterogeneous morphological characteristic. Lowest order is mostly dominates the basin. The foregoing analysis clearly indicates relationship among various attributes of morphometric aspects of basin which helps in sculpturing surface area of the region.

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PETROLOGY AND GEOCHEMISTRY OF GRANITES IN AND AROUND CHITYALA VILLAGE, NALGONDA DISTRICT, A.P., INDIA.

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ABSTRACT

Granites of Chityala area which is located close to Hyderabad, have been selected for a systematic study. Petrographic studies on granites include modal analysis. These studies indicate that the original magmatic structures have been completely obliterated because of the onset of subsequent petrogenetic processes. Further, replacement structures and textural intergrowth of perthite and myrmekite are commonly observed. Seventeen representative granite samples were subjected to major elemental analysis and 6 samples have been analysed for trace elements. The data obtained is plotted in various binary and ternary diagrams and trends of the major oxides and trace elements is observed. Geochemical variation diagrams do not indicate any definite origin for the granites of the investigated area.

Key words: Petrology and Geochemistry of Chityala Granites.

INTRODUCTION

The area under investigation (Fig. 1) falls in Toposheet no. 56 O/4 and is located in the Nalgonda district of Andhra Pradesh (Long: 79° 05' E – 79° 13' E and Lat: 17° 10' N – 17° 15' N). The distance from Hyderabad is about 75 kms and it falls in East of Hyderabad.

In the present study, an area of about 140 sq. kms is selected. Five major categories of rock types have been recognized on the basis of field, occurrence, mineralogy and textures in addition to colour (Fig. 2).

GEOLOGY

The area is sampled on the grid pattern and based on this sampled material the rocks have been classified into five major groups. The first group comprises of grey granites (Fig. 3) which include the porphyritic, gneissic, pyroxene and evenly granular grey granites. The second group comprises of pink granites which include the fine grained pink granites, pink alaskites and the coarse grained porphyritic varieties.

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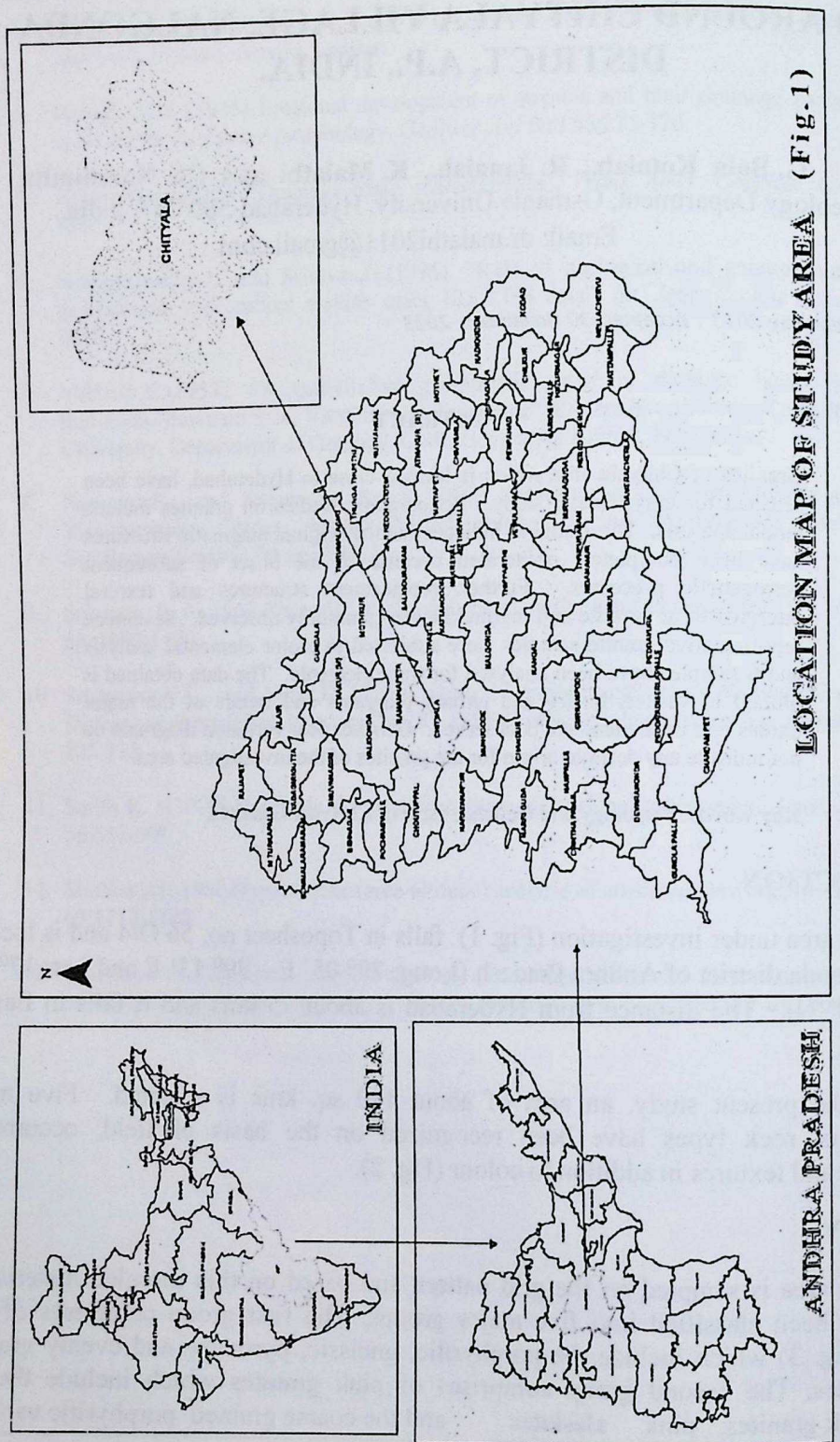

LOCATION MAP OF STUDY AREA (Fig. 1)

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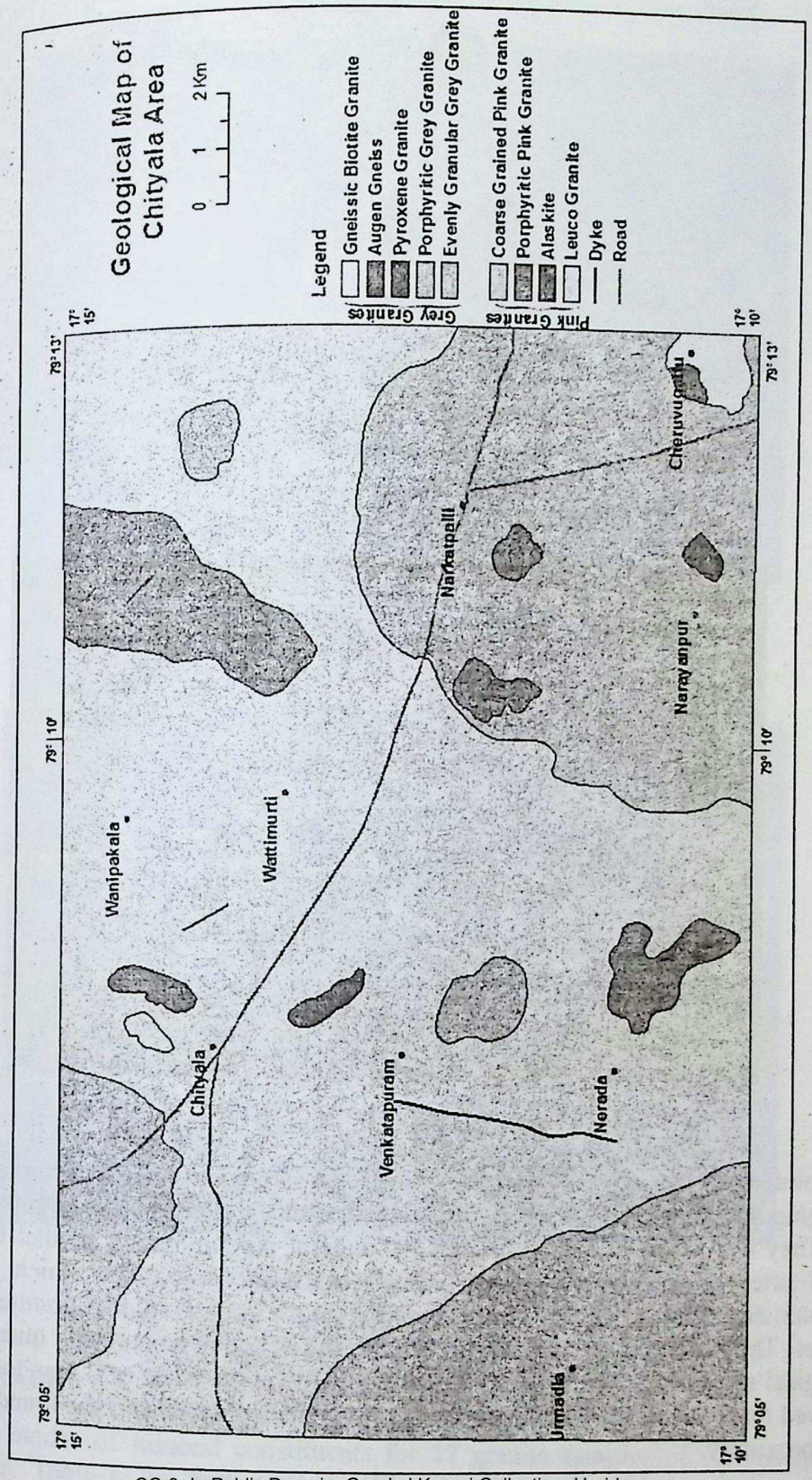

Geological Map of Chityala Area (Fig.2).

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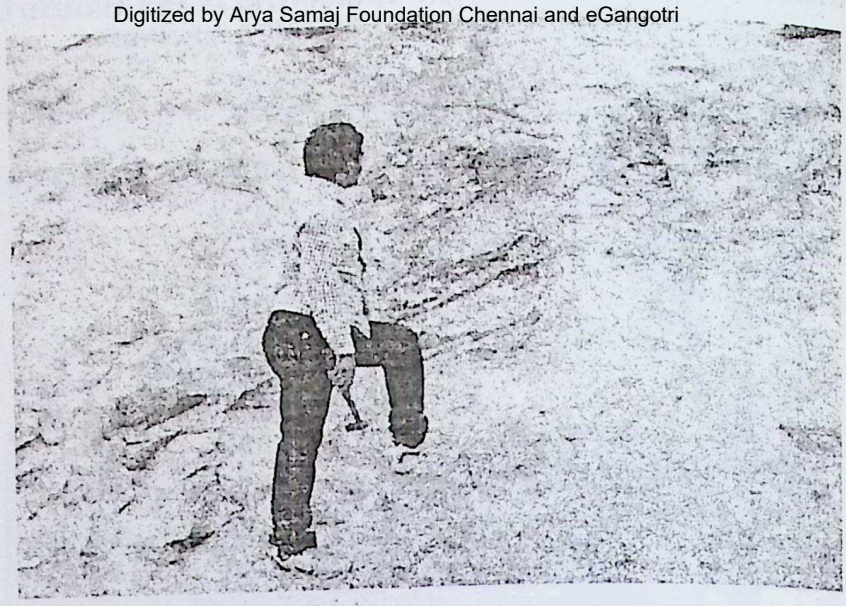

Fig. 3. Grey Granite quarrying near Lingotam village.

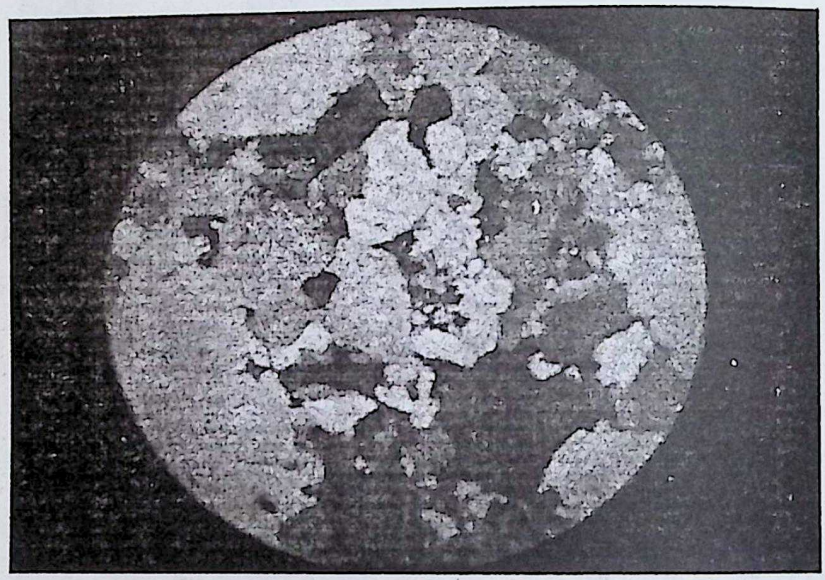

Fig. 4 Photomicrograph of pink Granite

The third group includes those rocks which have gradational characters. The rocks belonging to this category have no prominent colour and are usually admixture of the two. They also do not have any accessory mineral predominating so that they can be named after it. The fourth group comprises of those granites which have some characteristic features. In this group come the augen gneiss, epidote granites and leuco granites. The fifth group comprises of the basic dykes and pegmatite and quartz veins. A geological map of the area is prepared subsequently on the scale of 2 cms to 1 km. It is observed that most of the rock types show gradational contacts, and are found to occur in close proximity.

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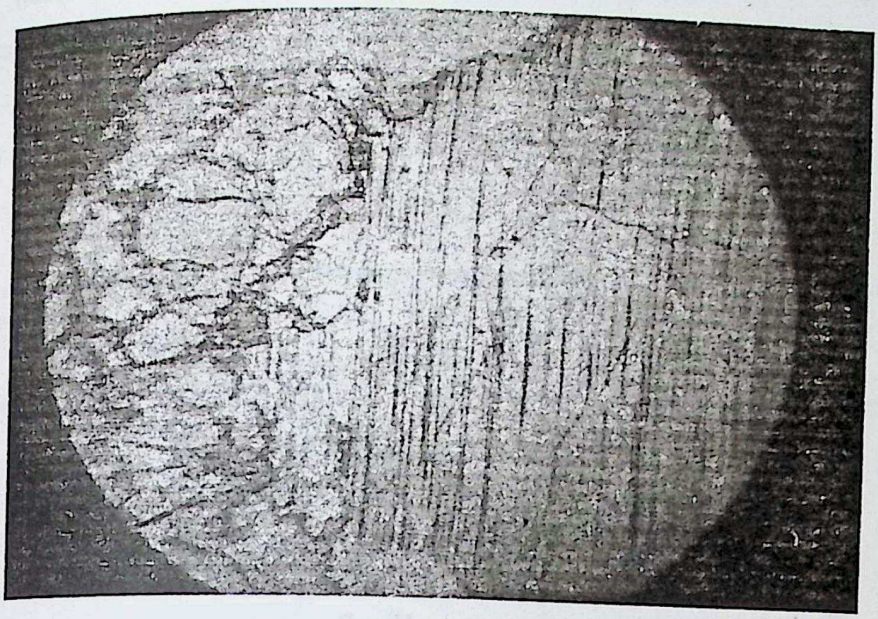

Fig. 5. Photomicrograph of Perthite in Granite

Fig. 6. Photomicrograph of Myrmekite in Granite

PETROGRAPHY

The modes of mineral constituents for 17 granite samples of various types is presented in Table-1. In thin sections (Fig. 4), the rocks chiefly contain quartz,

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plagioclase, perthites and K-felspars. Presence of myrmekite can also be observed. Among the accessory minerals, biotite is the most important. Other accessories include sphene, epidote and magnetite, rarely hornblende, apatite and zircon are seen.

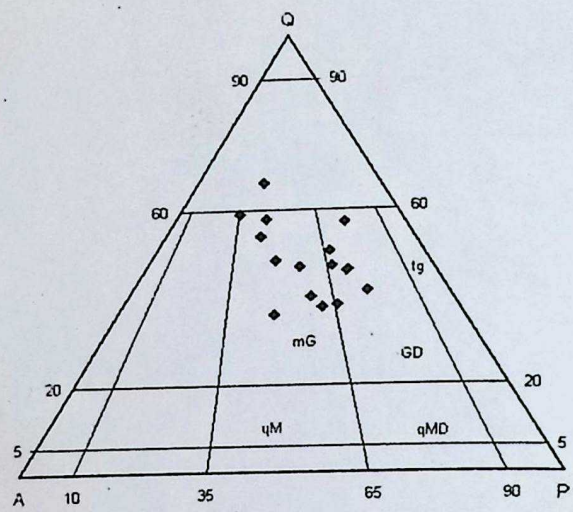

Fig. 7.

Quartz (Q) – Alkali feldspar(A) – Plagioclase(P) plot (Vol. %modes) of granites of the investigated area showing the classification of individual rock, qmd – quartz monzodiorite, tg – tonalite, GD – granodiorite, mG – monzogranite, qM – quartz monzonite (after Streckeisen, 1973 ; Le Maitre, 2002).

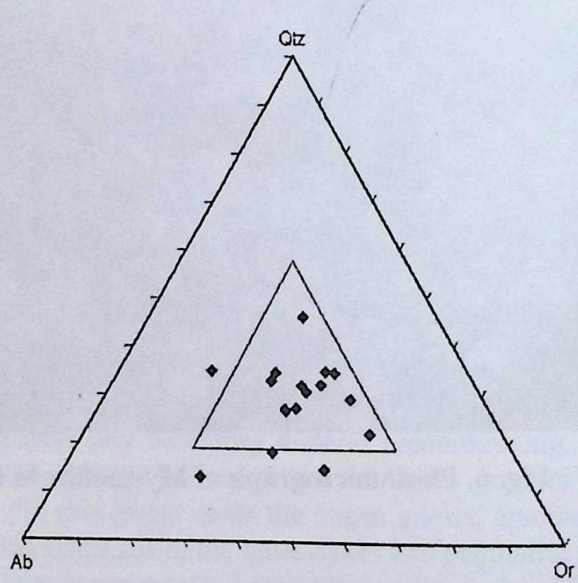

Fig. 8. Quartz – Albite – Orthoclase diagram for Chityala granites (After Tuttle and Bowen – 1960).

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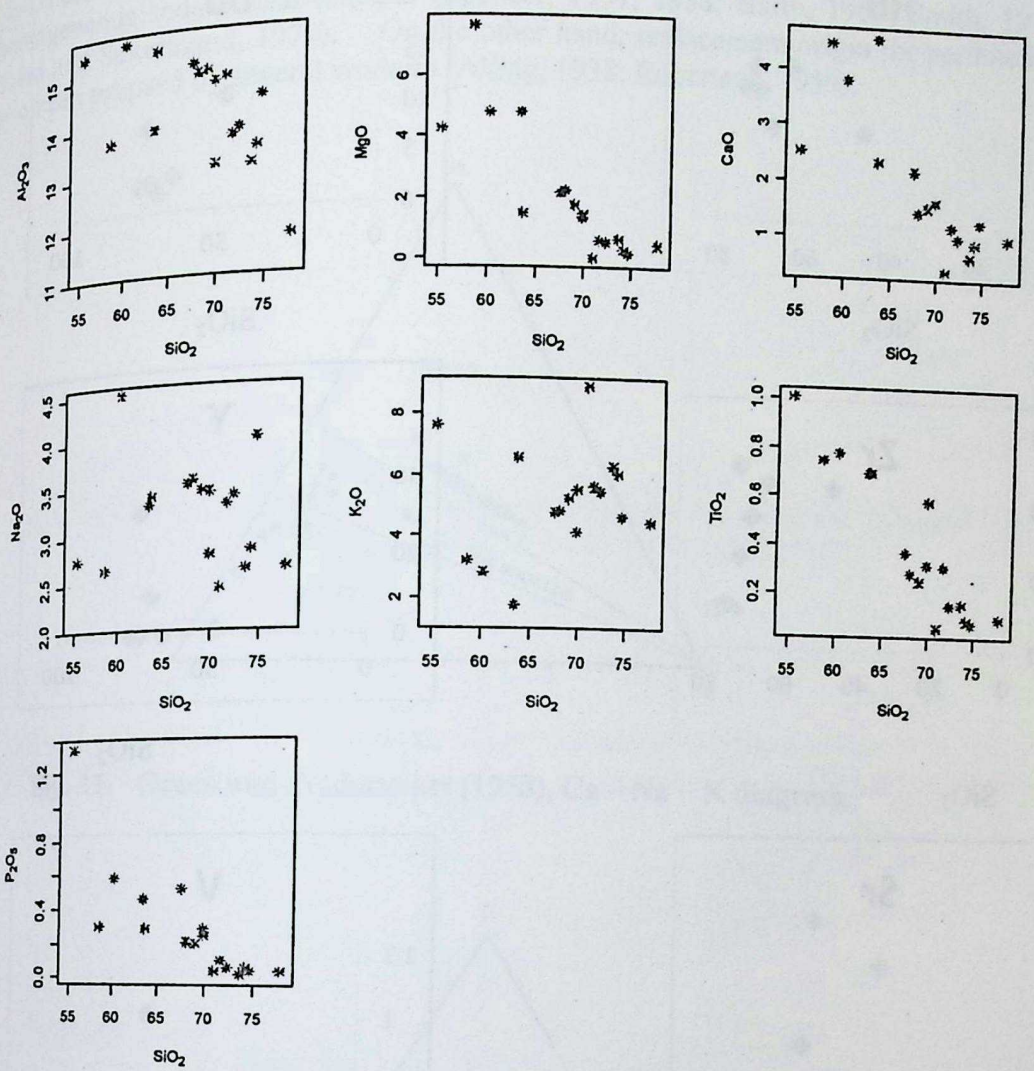

Fig. 9. Harkar's variation diagrams of SiO_2 vs selected major oxides for Chityala granites.

K - FELSPARS:- Orthoclase is the partially ordered monoclinic variety of potash feldspar whereas those which are nearly or completely ordered are the microclines and in between these two ends different amounts of triclinicity is exhibited by the natural occurrence. Hence perfect cross-hatched twinning in microcline is indicative of high triclinicity. This is why it has been argued that the orthoclase of old rocks will be converted into microcline by simple ageing (Mackenzie & Smith, 1959). However, Eskola (1952) has attributed this change from orthoclase to microcline due to mechanical deformation.

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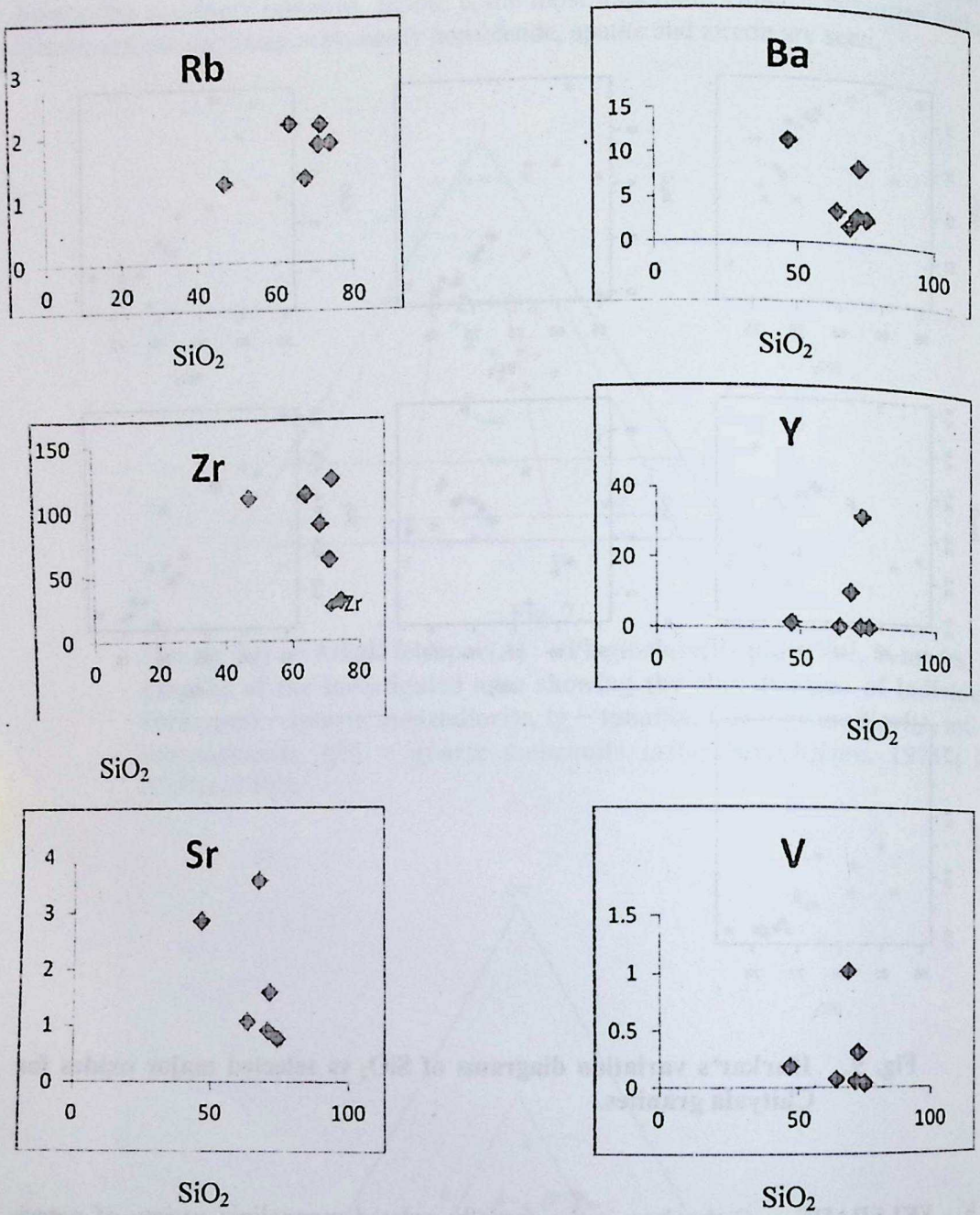

Fig. 10. Variations of trace elements in the Chityala granites.

PERTHITES:- Perthites (Fig. 5) occur in substantial amounts in granites. The perthitic intergrowth is mostly confined to microcline, whereas perthite associated with orthoclase is rarely observed. Perthites have been classified using their textural properties (Gates, 1953; Robertson, 1959) as hair perthite, film perthite, string perthite and bleb perthite etc.,

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Perthites are considered to be the result of exsolution of sodic phase from the homogeneous soda-potash feldspar (Spencer, 1937; 1938; Barth, 1969; Smith, 1974; Yund and Sekermand, 1979). On the other hand, replacement origin for perthite has also been propsed by several workers (Alling, 1938; Robertson, 1959).

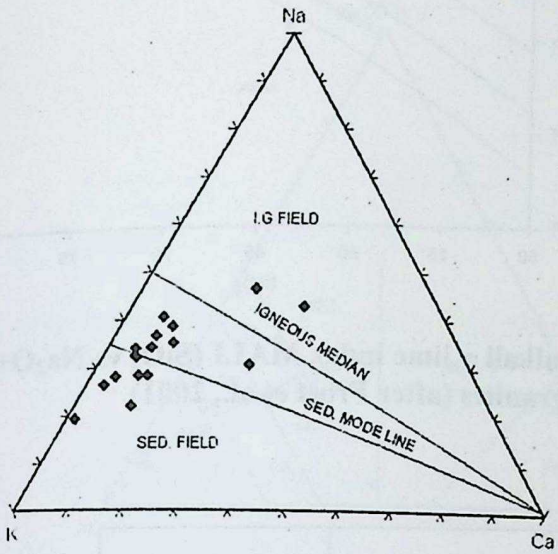

Fig. 11. Green and Poldervaart (1958), Ca – Na – K diagram.

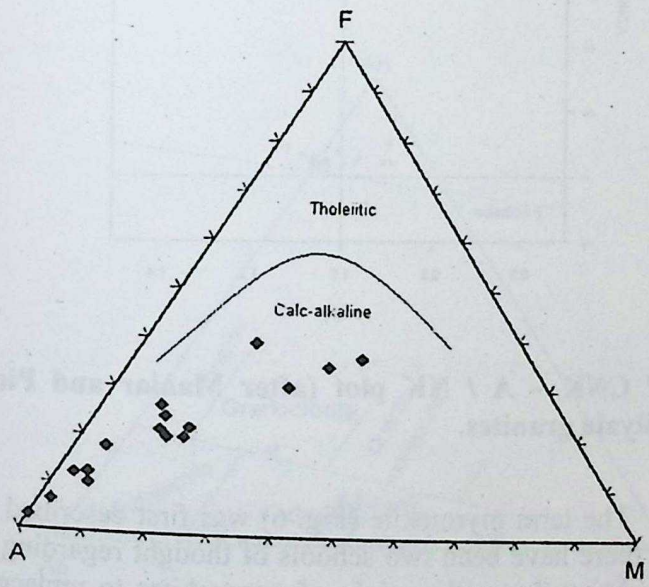

Fig. 12. AFM diagram (after Irvine and Baragar, 1971) for Chityala granites.

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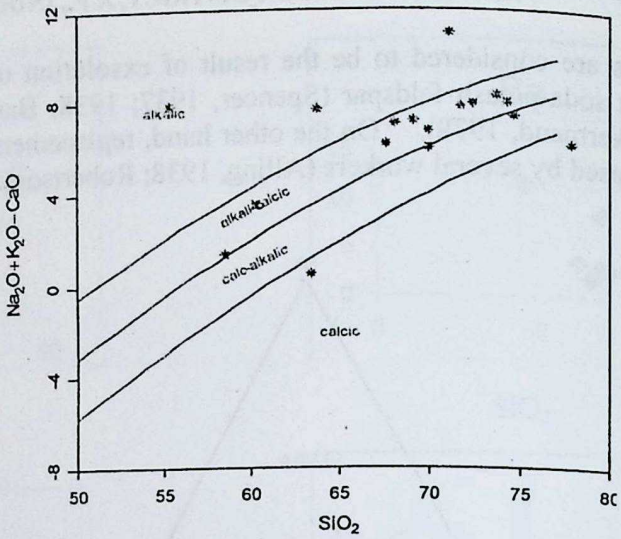

Fig. 13. Modified alkali – lime index MALI (SiO_2 vs $Na_2O+K_2O - CaO$) for Chityala granites (after Frost et al., 2001).

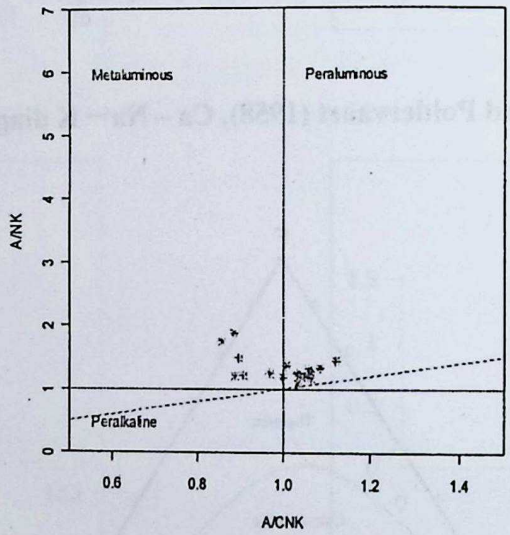

Fig. 14. A / CNK – A / NK plot (after Maniar and Piccolli, 1989) for Chityala granites.

MYRMEKITES:- The term myrmekite (Fig. 6) was first described by Sederholm in 1916. Since then, there have been two schools of thought regarding their origin. The first school of thought attributes the origin of myrmekites to replacement and in this school itself, there are two different view points; one is replacement of potash felspar by plagioclase (Sederholm, 1916; Binns, 1966) and the other is replacement of plagioclase by potash felspar (Dressher – Kaden, 1948; Osterwald, 1955). The second

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school of thought (Spencer, 1945; Ashworth, 1972) believes that both the components of myrmekites (quartz and plagioclase) is due to exsolution which are held in solid solution in the form of albite and K- felspar. Similar views have been supported by the experimental work of Carman and Tuttle (1963).

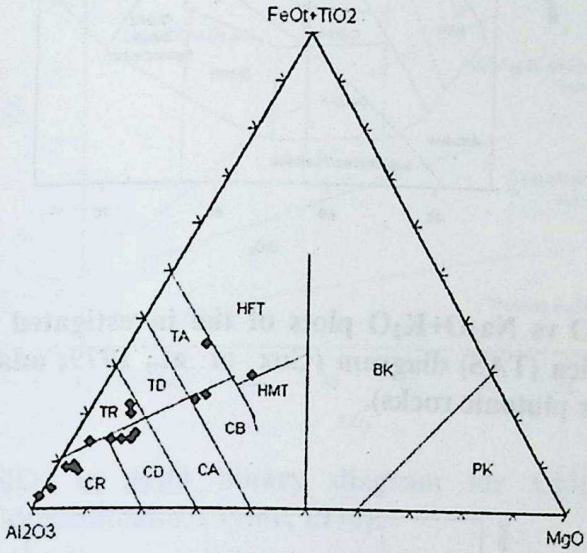

Fig. 15. Al_2O_3 – (FeO^t+TiO_2) – MgO ternary plot showing the evolutionary trend of Chityala granites. The various fields are taken from Jensen (1976). CD – calc – alkaline dacite, CA – calc – alkaline andesite, CB – calc – alkaline basalt, HFT – high Fe tholeiitic basalt, HMT – high Mg tholeiitic basalt

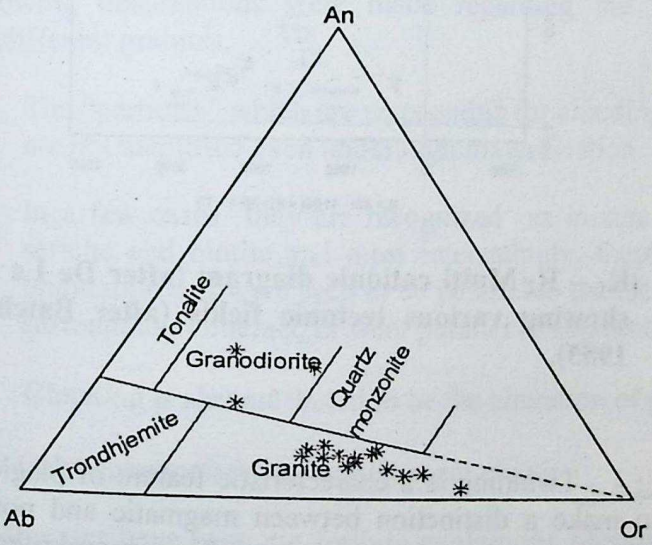

Fig. 16. Normative Albite (Ab), Anorthite (An), Orthoclase (Or) diagram for Chityala granites (Barker, 1979).

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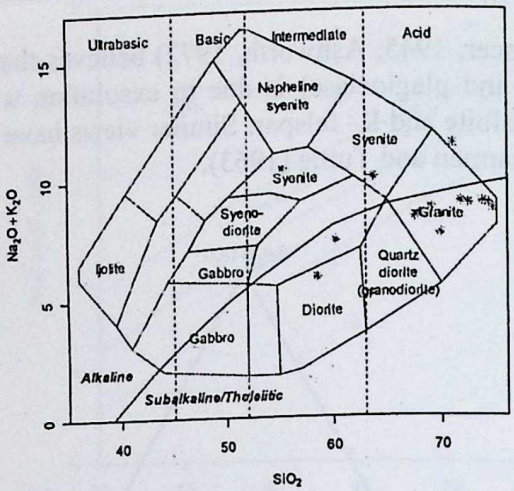

Fig. 17. **SiO vs Na_2O+K_2O plots of the investigated granites. Total alkali silica (TAS) diagram (Cox et al., 1979; adapted by Wilson, 1989 for plutonic rocks).**

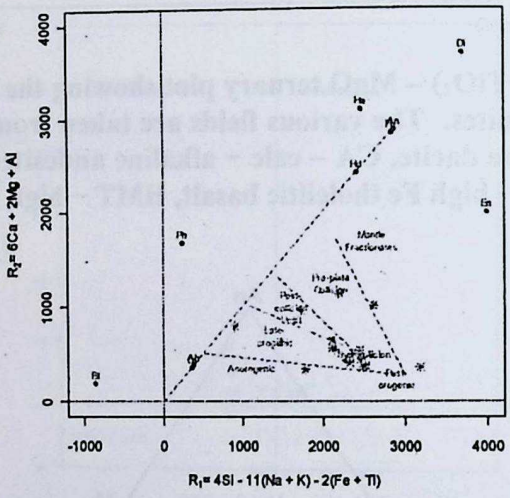

Fig. 18. **R_1 – R_2 Multi cationic diagram (after De La Roche et al., 1980) showing various tectonic fields (after Batchelor and Bowden, 1985).**

PLAGIOCLASE: - Twinning is a characteristic feature of plagioclase and has often been employed to make a distinction between magmatic and non magmatic granitic rocks. Turner (1951) gave the general characters of metamorphosed plagioclases. In the observed thin sections the lamellae tend to curve and taper to a point. They form clusters and tend to be thicker and more numerous at grain boundaries.

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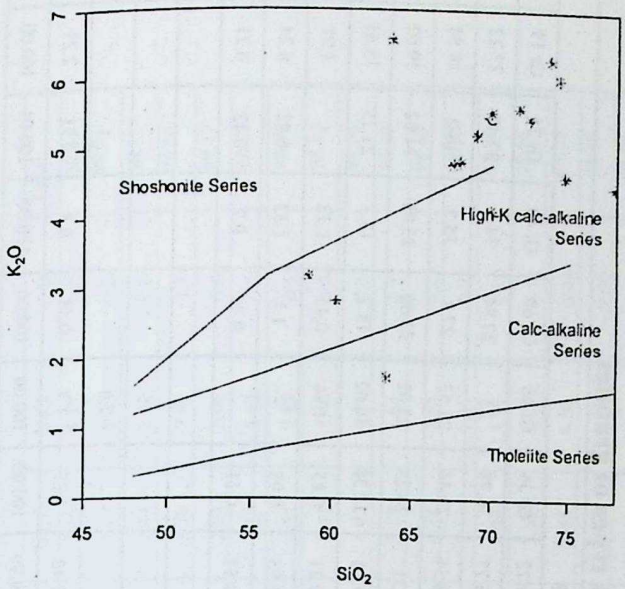

Fig. 19. **SiO_2 vs K_2O binary diagram for Chityala granites (after Peccerillo and Taylor, 1976).**

Clouding in Plagioclase: After observing many sections under microscope, it was found that plagioclases in all types of granites show clouding, the intensity being different for different types.

The following observations were made regarding the clouded plagioclases irrespective of different granites.

(a) The "particles" which are responsible for clouding are very minute and are not identified even under high magnification.

(b) In a few cases they are recognized as minute grains of magnetite, sericite and biotite and most interestingly, these showed a preferred orientation and were seen to be parallel to the cleavage planes of other surrounding minerals, or were parallel to adjacent crystal boundaries.

(c) Clouding is also attributed to be the alteration of plagioclase.

(d) Calcic plagioclase are usually more cloudy.

Several theories have been put forth to explain the phenomenon of clouding in plagioclase (Shand, 1945., Poldervaart and Gilky, 1954., Pichamuthu, 1959., Janardan Rao, 1964c). However, it is generally believed that the clouding is due to the presence of numerous minute dark particles of minerals such as magnetite, biotite and hornblende and their alteration products.

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Table. 1.

Modal analysis. Volume percentage of various types of granites.

Minerals	Sample Numbers																	
	Gr 39	Gr 54	Gr 42	Gr 55	Gr 28	Gr 06	Gr 71	Gr 35	Gr 34	Gr 56	Gr 72	Gr 36	Gr 66	Gr 68	Gr 40	Gr 75	Gr 15	Average
Quartz	35.48	31.12	41.57	20.85	45.02	38.75	27.42	36.78	40.07	31.55	26.77	36.78	25	27.84	34.3	37.49	27.22	33.1771
Plagioclase	21.7	25.65	8.24	17.15	8.56	11.54	22.51	23.44	13.45	17.62	28.51	23.44	21.52	27.8	25.2	18.2	28.54	20.1806
Perthite	20.95	22.38	27.85	29.87	28.51	31.02	30.75	24.23	15.72	38.17	31	24.23	23.02	23.68	23.05	14.62	19.02	25.1806
K-felspar	18.37	10.94	20.51	19.92	14.49	16.7	9.35	12.38	20.76	5.98	9.54	12.38	16.02	18.2	13.3	21.75	15.51	15.0617
Myrmekite	0.75	-	1.02	0.24	2.56	1.86	-	0.83	0.27	1.56	0.21	0.83	4.94	0.45	1.32	-	1.05	1.0524
Biotite	1.2	4.71	0.24	6.07	0.51	-	2.07	0.98	7.95	3.72	1.95	0.98	-	1.1	1.33	6.82	6.24	2.6982
Magnetite	0.42	0.64	-	-	0.23	-	-	0.11	0.51	0.16	0.51	0.11	-	0.35	0.7	0.42	0.21	0.2571
Epidote	-	1.15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0676
Hornblende	-	3.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1835
Augite	-	-	-	4.58	-	-	5.92	-	-	-	-	-	7.8	-	-	-	-	1.0765
Others	1.1	0.21	0.58	1.33	0.12	0.14	1.98	1.73	1.27	1.26	1.48	1.25	1.7	0.58	0.8	0.71	2.21	1.0853
Total	99.97	99.92	100.01	100.01	100.00	100.01	100.00	100.00	100.00	100.02	99.99	100.00	100.00	100.00	100.00	100.01	100.00	99.9965

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Table. 2.

Whole rock major oxide compositions of various types of granites from the Chityala area in weight percentages.

Sample Numbers **Oxides**

Sample	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Total
RJ39	69.95	14.74	0.32	2.42	0.03	1.34	1.63	3.46	4.15	0.29	98.34
RJ54	69.07	14.95	0.25	2.59	0.02	1.76	1.52	3.47	5.22	0.20	99.04
RJ42	71.04	14.84	0.06	0.35	0.00	0.02	0.39	2.44	8.92	0.04	98.11
RJ55	55.31	15.42	1.01	9.41	0.04	4.26	2.54	2.76	7.60	1.34	99.69
RJ28	74.25	13.46	0.09	1.23	0.01	0.29	0.89	2.84	6.04	0.06	99.17
RJ6	71.74	13.68	0.31	2.03	0.03	0.59	1.18	3.33	5.62	0.10	98.67
RJ71	60.27	15.59	0.78	5.28	0.08	4.79	3.81	4.51	2.83	0.58	98.52
RJ35	72.42	13.83	0.15	1.30	0.02	0.51	0.99	3.41	5.46	0.06	98.14
RJ34	74.67	14.43	0.08	0.60	0.01	0.19	1.29	4.03	4.64	0.04	99.96
RJ56	68.03	14.91	0.28	2.94	0.02	2.21	1.43	3.59	4.84	0.21	98.47
RJ72	69.96	13.13	0.58	3.08	0.04	1.43	1.63	2.79	5.55	0.25	98.43
RJ36	73.71	13.13	0.16	1.06	0.01	0.65	0.65	2.64	6.31	0.02	98.37
RJ66	58.53	13.67	0.75	7.62	0.13	7.65	4.5	2.64	3.19	0.30	98.98
RJ68	67.59	15.09	0.37	2.58	0.03	2.13	2.19	3.54	4.80	0.52	98.86
RJ40	77.83	11.73	0.10	1.05	0.02	0.44	0.98	2.66	4.50	0.04	99.35
RJ75	63.46	13.87	0.70	5.16	0.07	4.79	4.59	3.32	1.75	0.46	98.16
RJ15	63.71	15.40	0.70	4.07	0.04	1.46	2.33	3.42	6.58	0.29	98.01
Average	68.3259	14.2276	0.3935	3.1041	0.0341	2.03	1.9141	3.2455	5.1765	0.2824	98.6629

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Table. 3.
CIPW Norm Compositions of Granites From the Study Area.

Minerals — **Sample Numbers**

NORM	Gr 39	Gr 54	Gr 42	Gr 55	Gr 28	Gr 06	Gr 71	Gr 35	Gr 34	Gr 56	Gr 72	Gr 36	Gr 66	Gr 68	Gr 40	Gr 75	Gr 15
Quartz	28.574	22.788	21.869	0.00	32.04	27.18	8.324	28.583	30.362	21.946	26.815	31.612	9.288	21.51	42.155	20.729	11.769
Corundum	2.286	1.306	0.557	1.243	0.775	0.212	0.00	0.654	0.528	1.668	0.168	0.823	0.00	1.334	0.797	0.00	0.00
Orthoclase	24.525	30.849	52.714	44.914	35.695	33.212	16.724	32.267	27.421	28.603	32.799	37.29	18.852	28.367	26.594	10.342	38.886
Albite	29.278	29.362	20.647	23.354	24.031	28.178	38.162	28.854	34.101	30.378	23.608	22.339	22.339	29.995	22.508	28.093	28.939
Anorthite	6.192	6.234	1.647	3.847	4.023	5.201	13.936	4.52	6.139	5.722	6.453	3.094	16.028	7.468	4.601	17.774	7.234
Nepheline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diopside	0.00	0.00	0.00	0.00	0.00	0.00	0.939	0.00	0.00	0.00	0.00	0.00	3.462	0.00	0.00	1.59	1.981
Hypersthene	4.864	6.148	0.24	14.381	1.608	2.69	14.706	2.134	0.855	7.508	5.223	2.249	22.701	6.881	1.835	14.41	4.951
Olivine	0.00	0.00	0.00	1.752	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Magnetite	3.509	3.755	0.507	13.644	1.783	2.943	7.656	1.885	0.87	4.263	4.466	1.537	11.048	3.741	1.522	7.482	5.901
Ilmenite	0.608	0.475	0.114	1.919	0.171	0.589	1.482	0.285	0.152	0.532	1.102	0.304	1.425	0.703	0.19	1.33	1.33
Apatite	0.687	0.474	0.095	3.174	0.142	0.237	1.374	0.142	0.095	0.497	0.592	0.047	0.711	1.232	0.095	1.09	0.687
Total	100.523	101.391	98.417	108.228	100.27	100.442	103.303	99.323	100.522	101.117	101.225	99.295	105.854	101.189	100.297	102.838	101.678

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Table. 4.

Whole rock trace elemental compositions of various types of Granites from the study area in ppm.

Sample Numbers Trace Element

Samples	Zr	Ba	Sr	V	Y	Rb
Gr06	124	8.58	1.6	0.316	32	2.156
Gr 35	113	3.58	1.07	0.083	0	2.17
Gr 36	31	2.77	0.76	0.039	0	1.852
Gr 40	63	3.01	0.9	0.059	0	1.826
Gr 54	110	11.45	2.87	0.192	1.2	1.262
Gr 66	90	1.93	3.57	1.02	10.2	1.309
Average	88.5	5.22	1.795	0.2848	7.2333	1.7625

Two diagrams are drawn based on modal compositions and the figures prove that the rocks are granites. Plots of Quartz – Alkali felspar – Plagioclase for granites of the investigated area largely corresponds to monzo granite and granodiorite (Fig. 7). Plots of Quartz – Albite – Orthoclase (Fig. 8) reveal that most of the rock samples fall in the "Average Granite" field.

GEOCHEMISTRY

Seventeen representative granite samples were subjected to major elemental analysis and 6 samples have been analysed for trace elements. The data obtained is plotted in various binary and ternary diagrams and the trends of the major oxide and a trace element is observed.

The major oxides data along with their C I P W Norms are given in tables 2 and 3 and the trace elemental data is given in Table no: 4

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By observing the diagram (Fig. 9), it is seen that with the increase in SiO_2 content, oxides like TiO_2, MgO, P_2O_5, Al_2O_3 and CaO show a slightly decreasing trend, while the oxide like Na_2O shows marked scatter and K_2O shows a slight increase.

Variation diagrams of trace elements versus SiO_2 (Fig. 10) depicts mild to moderate negative trend with Sr, Ba, Zr and V and positive trend of Rb while Y do not define any discernible trend.

The plots of SiO_2 against various oxides and trace elements (Figures 9 and 10) suggest that they are formed by mixing of mafic and felsic magmas in various proportions (Kumar and Rino, 2006).

Ca – Na – K diagram (Fig. 11) indicates broad range in composition of felspars which in turn points to different sources of parent materials (Green and Poldervaart, 1958).

$Na_2O + K_2O - FeO^t - MgO$ (A F M) triangular plot (Fig. 12) indicates the fractional crystallisation (Nockolds and Allen, 1953 ; Thornton and Tuttle, 1969).

In this modified alkali-lime index ($Na_2O + K_2O - CaO$ vs SiO_2) diagram (Fig. 13) most of the plots fall in alkali – calcic field while few of them fall in calc – alkalic, calcic and alkalic field.

The diagram of Al_2O_3 / $CaO + Na_2O + K_2O$ vs Al_2O_3 /$Na_2O + K_2O$ (Maniar and Piccolli, 1989) shows weak to moderate peraluminous to metaluminous nature of Chityala granites (Fig. 14).

Figure 15 in terms of $(FeO^t + TiO_2) - Al_2O_3 - MgO$ indicates the various types of magmatic parental material (Jensen, 1976) for Chityala granites.

In normative Albite (Ab) – Anorthite (An) – Orthoclase (Or) diagram (Barker, 1979) most of the samples are clustered mainly in granite field and a few low silica grey granites straddle close to the boundary between granite and granodiorite field (Fig. 16).

SiO_2 vs ($Na_2O + K_2O$) plots of the investigated granites (Fig. 17) straddle in the field for granite and reveal their subalkaline nature. The formation of granites with such geochemical characteristics is known to take place from the partial melting of crustal metasedimentary rocks (Chappell and White, 1974).

On the geotectonic descrimination diagram (Fig. 18) based on multicationic R_1 – R_2 factors as proposed by De La Roche et al., (1980), Chityala granite samples plot dominantly in syn-collisional field.

Figure 19 (SiO_2 vs K_2O) indicates that most likely the source materials for melt (for Chityala granites) appear hydrated, high K calc-alkaline andesite and basaltic andesite which may evolve into shoshonite. The inferred source materials could be derived from enriched subcontinental lithospheric mantle (Selvam et al., 1995).

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CONCLUSIONS

Field investigations and petrographic studies indicate that the original magmatic characters present in the basement rocks have been completely obliterated because of the onset of subsequent petrographic processes. Further, replacement structures, textural intergrowths and mineral paragenesis indicate the origin of granites by metamorphic and metasomatic processes. Geochemical variation diagrams do not give a definite origin for the granites of the investigated area.

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IMPACT OF MIGRATION IN ECONOMIC AND SOCIAL OF RURAL ENVIRONMENTS

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ABSTRACT

Migration from rural area to cities is a popular problem in many countries. There are many researches about migration but however, return migration has not been much researched, especially not research on internal remigration of the poor voluntary migrant workers. This research was implemented in rural area of Iran. We want to response two questions as well as to clarify three issues: 1) the reason why migrant workers return to their home village; 2) the social and economic impacts for the returnees and their families. The result of study shows that all processes of the migration up to remigration of the people in this village were generalized. However, two core reasons of returning to migrants to home are due to the fact that most of the short term returnees could not adapt to the living and working conditions in the destinations, and the seasonal returnees mostly returned to the home village because of rice crop season in the countryside.

Keywords: Return migration, Ethnological approach, Internal remigration Iran.

1.INTRODUCTION

Migration was considered an equilibrating mechanism that through labor transfer from the surplus labor to the labor deficit sector, finally brought about wage equality in the two sectors (Bilsborrow et al., 2001). For many developed and developing countries, migration has become a crucial issue (Thanh, 2008). On the other hand, migration played an important role in poverty reduction through remittances sent back to the original country or village in the low-income countries. In addition, in the livelihood approach, migration was considered as a livelihood strategy by livelihood diversification in rural areas (Thanh, 2009).

Low income and poor living conditions in rural areas, the scarcity of non-farm employments with high incomes has been driving rural workers to look for work in cities. Firstly, there is shortage of agricultural land areas in the rural areas and too few rural employments while high population growth. Secondly, transformation of models in agricultural production also created a surplus labor force in rural areas (Thanh, 2009). Livelihood diversification away from agriculture as well as diversification of income sources in the rural areas was considered the primary means of the household survival

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(Thanh, 2008, 2009). Since then the strategy for leaving the rice fields but not the countryside'has been formed. People diversified their income sources by joining in non-farm sectors and migrating to other places to find jobs. Hence, more and more rural people have been moving into cities or urban areas as temporary migrants. Those were internal migration inside the country. Migration has been considered a complex sequence of moves that might include several destinations and regular contact with the origin, which might eventually comprise of return migration. Moreover, in opposition to migration, it was recognized that migration flows often tended to generate "counter flows" - mostly return migration. This was inherent to the concept of circular migration. Issues of return migration processes remain to be understood, as they are complex and multilayered. Return migration was defined as the voluntary movements of immigrants back to their original places. This was also known as circular migration. Returns broadly were described in three different ways. For instance, the return might be voluntary without compulsion, when the migrants made a decision at any time during their temporary stay to return home at their own choices and cost. The voluntary under compulsion, when people were at the end of their temporary protected status, refused asylum, or were unable to stay, and chose to return at their own choices. The involuntary, as a result of the authorities of the host State ordering deportation. Return migration to the home country whether temporary or permanent, was able to contribute to decreasing the negative effects of human capital outflows for original countries. Return migration could both enrich the human capital of original countries and contribute to the transfer of technology and of scientific, technical, and economic expertise as well as political, social, and cultural exchanges (Bourdieu and Wacquant, 2002). The return migrants from developed countries could take advantages of the migration to be trained jobs and to approach education (for low educated migrant only) (Brauw and Harigaya, 2007). Cassarino addressed the factors motivating the interviewees' departure from their country of origin; the impact of the migratory experience abroad on the interviewee's pre- and post-return conditions; and the various post-return conditions of the returnees and their prospects of reintegration (Breckner, 2000). And definition of return migrant or returnee was described by Cassarino and Gubert as any person who returned to his or her original country, in the course of the last ten years, had been an international migrant (whether short-term or long-term) in another country. Return might be permanent or temporary. It might be independently decided by the migrant or forced by unexpected circumstances.. In other word, Bilsborrow et al (2001) defined return migrant or returnee as a person returns to the home village, town or city where he or she was usually living before migration, he or she should be considered as a return migrant even if he or she did not return to the same house or household. (Bilsborrow et al., 2001).

Adda(2006) indicated that specific economic conditions were to be important to both migration decisions to emigrate from the home country and to return to it. Additionally, it was focused on the fact that many migrants today returned to their home countries in crowds after having spent a number of years in the host country (Brettell, 2000). The remigration has been due to involuntary return and/or voluntary return.

How does the return migration have economic and social impacts on the returnees and their households?

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The main research question raises the substantive questions:

1. Why did migrant worker return to the original village?
2. How did the remigration affect the migrants, the household where they stay, and the village at large?
3. What strategies do the migrants use to re-adapt to the life of the home villages?
4. What strategies do the villagers that have remained use to adapt to the return migrants?

2.LITERATURE REVIEW

This section will give a short description of migration process, reasons for remigration and effects of remigration on socio-economic and cultural aspects of the returnees. The focus is on migrant workers and spontaneous migrants who migrated to seek for jobs in many places in Iran far from their home village.

All documents referenced in this study were synthesized from the process of international migration and return migration, even though the process of return migration in Iran also happened at the international scale that means the remigration process of migrant returnees was taken place from the other countries to Iran. Although the process of the return migration happened in different countries and my study only focused on the regional scale within Iran, the references were very useful in finding and comparing similarities and differences in reasons for migration, working and living conditions, and influences on social, economic, and cultural aspects during the process of the migrant worker return

2.1 REASONS FOR MIGRATION

In terms of the motivation for migration as well as the reasons why people left their home village to the other places to live or to find jobs for improving income, there have been many various reasons for migration in many different countries. According to International Labor Organization (ILO), migration researches in many countries (Denmark, the Netherlands, Belgium, France, Austria, Switzerland, Germany, the United States, Canada, Australia, South Africa and Luxembourg), addressed many motivations behind individual decisions to migrate. It was evident that lack of satisfactory opportunities at home was the main reason driving to the contemporary growth of migration pressures and emigration might help to ease or reduce population pressures and unemployment (ILO, 2004). In the case of the Western Sudan, people decided to migrate because of severe drought and starvation (Cassarino, 2008). Moreover, the findings in the research of Cassarino (2004) showed that the migrants left their homeland for a few reasons relating to work opportunities, such as the outbreak of the war, for pursuit of their studies or for family considerations. Another idea showed that high levels of unemployment and underemployment in the poorer countries were contributing to pressures for more migration (Jones, 2008).

In terms of concerns of working conditions and the behavior of the migrant workers in destinations, there were many ideas mentioned to this issue. However, before going to the detail of this part, I would like to give a short brief description of labor

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regulation including the labor right, and how it was applied in Iran. It was referenced in *the Labor Code of Iran*. These articles below were cited in the labor law.

The labor regulation of Iran prescribed the rights of the workers and their employers, the labor standards, the principles to use and to manage the laborers. The Labor Code protects the labor rights, benefits and other rights of the laborers as well as protects the legitimate rights and interests of the employers in order to facilitate for the labor relations to be harmonious and stable.

As the migration mentioned above, many migrations now a days were temporary (Adda et al., 2006) and the dynamics, and links between return migration and development has interested various national and international actors, comprising of intergovernmental and non-governmental organizations, migrant associations, and the private sectors. Similar to before the migrants departure stage, migrants return for different reasons and for different lengths of time. In addition, the reasons for return were considered push and pull factors in many countries at the international level.

In the trend of the international integration and globalization, Iran was among countries having a big number of people emigrating abroad. The migrants almost stayed in every countries and territories of the world. Every year, many of them return to Iran with different purposes: permanent stay (repatriation), visiting their relatives, investment, doing their business. etc. (ILO, 2004). Some migrants failed to meet their expectation of emigration experience; others decided to return when they have saved sufficient funds. Nevertheless, often the deciding factor would be the situation in their country of origin: if the economic promise improved, then returning would be more attractive. When these migrants came back with skills or savings, this was able to make a welcome contribution to development (ILO, 2004).

This section will give a short description of migration process, reasons for remigration and effects of remigration on socio-economic and cultural aspects of the returnees. The focus is on migrant workers and spontaneous migrants who migrated to seek for jobs in many places in Iran far from their home village.

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In Southeast Asia, there have been many migration studies in both scope and number, but it has not been known much in Iran. Population mobility has increased significantly in Iran not only because of the major cause of interregional variations in

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population growth, but also because of its influential role in social and economic change in the affected areas (Dang *et al.*, 1997). Dang *et al.*, (1997) pointed out that there were four major phases of migration in Iran.

Today, return migrants have increasingly characterized by transnational networks, reflecting new migration circumstances that have been developing at the beginning of the 21st century (De Souza, 2006). Most of return migrants were increasingly the young, who were exported workers in the host countries and internal return migrant workers in IZs or in farms. The return migration included both of the skilled and unskilled return migrants. The skilled return migrants were poised to become more important to local government policy. Moreover, they held the potential to help build global networks, forge further links between sending and receiving countries, and directly contribute to development efforts. According to the International Organization for Migration (ILO) in the 1990s, a program of "Migration for Development" was implemented in several countries in Africa and Eastern Europe. Country officials have instituted innovative policy strategies to reach out to this skilled migrant pool. For instance, China and the Republic of Korea persuaded the expatriate researchers back home in order to concentrate high-tech industries or science-related businesses. The governments of the countries have implemented policies to facilitate the long-term re-entry of migrants. For instance, since 1993 the government of Jamaica has been working in order to identify re-entry problems, to reduce red tape, and to propose solutions to common bureaucratic constraints, which returnees faced. Moreover, other policies targeted overseas workers. In the Philippines, for example, Overseas Workers Welfare Administration of the government supports an intergovernmental agency referral system, which was called the Replacement and Monitoring Center. This Center offered returnees job placement services, skills training, livelihood programs, and job opportunity assessments, and gave employers a database of skilled migrant workers. Return migrants have also been encouraged to spend or invest in their homelands, frequently through partnerships with the government and the private sector. In Guyana, for example, the Guyana Office for Investment was established in 1994 in order to attract and facilitate increase in investment to fuel through efficient and effective investor services.

3.RESEARCH METHODOLOGY

Based on the empirical study of return migrant workers in Village, this research was conducted during two phases between June and August of 2009, and between November and January of 2010. The study investigates the socio-economic effects of re-migration to rural areas on the returnees 'households after the workers came back to their home village.

In any case study, the choice of case is one of the greatest significance for the possibility of generalizing theories and identifying general categories. Based on this assumption, I selected Village as my research site.

3-1- Data collection

This study aims to determine the social and economic effects of re-migration on the returnees after coming back the original village among voluntary return migrants. The

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research subject is thus voluntary re-migration of workers in the case of migrant people in Gilng province, Iran.

3-2- Sample size

This study was mostly qualified as a descriptive study. In total, three group discussions were conducted including one group of non-migration (12 participants), and two groups of migration: seasonal migrants (15 participants) and short-term migrants (10 participants). For non-migration, twelve of male and female laborers in Village were invited, these laborers were those who are poor and landless or have little land. They were the young, the middle age, and the older labor. All of them were at the working age from 18 to 60 years old for the man and from 18 to 55 for the woman. Besides that, fifteen seasonal return migrant workers were also invited. These seasonal returnees included the male and female laborers who returned from the different destinations. They were also in the poor households being landless or having little land. They were the young, the middle age, and the older labor. Moreover, all of them were at the working age. However, some of them were younger than 18 years old, about 15 years old, because all male and female who were allowed to have Identification (ID) card at the age of 15. All of the participants in group discussions and in-depth interviews were in both nuclear and extended families.

Together with group discussions, a total of twenty-five returnees within the study site were randomly selected as the target population of the study and were invited to in-depth interview. The number of returnee respondents and the number of participants joined in group discussion in the village were shown (Table 2). Among six non-migrants in the village, they were poor villagers in the households with landless and little land and including the young, the middle, and the older labor. Similarly to those non-migrant respondents, the return migrant workers including seasonal and short-term migrants who were representative for groups of labor remigration from different occupation and working places were interviewed. These returnees were in the nuclear and extended families. They also were in the poor households with little land and landless in the village. They returned from the different companies in different worksites. All respondents who were randomly selected were male and female, at the age of 15 to 56. Among nine-teen returnees, there were ten interviewees coming back home due to seasonal crops, and nine people coming back home due to the fact that they could not adapt to the working conditions in the city, so they could migrate to work less than three months (short term migration). Besides that, returnees in the research site chosen were based on the following criteria:

i) Both of return migrant workers and inhabitants in this study were the poor people who were landless or had little land for agricultural production.

ii) Migration group is classified based on types of migration: seasonal and short-term migration, workers had left their home village for seeking jobs and they came back from the cities or other places in Iran as a voluntary migrant.

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iii) This criterion required that the returnees were able to remember the entire migration period as well as his or her full migration story from the beginning onward, even though it took place a long time ago.

iv) An additional criterion was that returnees were those who migrated to the cities or urban areas at least one month and then came back original village.

Table 1:Number of group discussions in the village

Types of migration	Number of participants
Non-migration	12
Seasonal migration	15
Short term migration	10
Total:	37

Table 2:Number of respondents in in-depth interview in the village

Types of migration	Number of interviewees
Non-migration	6
Seasonal migration	10
Short term migration	9
Total:	25

).3-Problem analysis

After all data collected from different sources such as secondary data, literature, group discussion, individual surveys via in-depth interviews and key informant interviews, and the participants observation will be analyzed. These data were used for analyzing changes within three capitals (economic, social, and cultural) as well as influences on local livelihoods, social relations and perception or experiences of the returnees after back home village. After the returnees came back their home village, the adaptation strategies were described. Furthermore, the information of support policies for both the returnees and villagers would be mentioned.

4.RESULT AND DISCUSSION

The aim of this section is to present the major findings of the research with an effort to account for why return migration to Village has taken place, the effects on returnees and their households of the return and how they adapt to the remigration process in the origin village. Before doing so, a brief background of the profiles of the returnees will be provided by emphasizing the circumstances related to their decisions to break away from and then return to their home village.

ILO (2004) points out that there are many ways to classify migrant workers based on incentives, skills, age, occupation or distance from origin; the categories most commonly used are based on anticipated duration of stay. Firstly is permanent migration, primarily for highly skilled migrants, family unification, and refugee resettlement. Secondly is temporary migration for all types of employment. This door allows the entry of migrants, commonly known as guest workers, to fill vacant jobs, such as nursing positions. Finally is temporary migration for time-bound employment. The entry of

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migrants to fill seasonal jobs – jobs that will end with the completion of a project, e.g. a construction – and service providers, trainees and students (ILO, 2004).

Firstly is seasonal migration. With this type of migration, rural employees move to the urban areas, especially in the cities and industrial zones or farms in order to search for jobs and contribute income to the family. The migrant workers often migrate in the middle of rice crop season and during the flood season. Each year they grow two rice crops in Winter-Spring crop and Summer-Autumn crop. In Winter-Spring crop, they stay at home from two or three first weeks of December for preparing the new rice crop and two or three late weeks of March for harvest rice. In Summer-Autumn crop, they continuously stay at home from two late weeks of March to the first week of April for preparing new rice crop and two first weeks of July for harvest rice. After the rice crop is sown, or harvested, the laborers will come back to the city to continue their work or to seek new jobs. Their particularity of jobs is repeated each year. The majority of them are voluntary unskilled migrant workers working in construction companies. Moreover, these migrant workers who are mainly male laborers look healthy and are under the age limited.

Figure 1. Seasonal calendar of the seasonal returnees in Village

Activities	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
Growing rice	S-W crop			S-A crop				Flood season				S-W
Construction worker	middle crop				Middle crop			in the flood season				
Agri. hired labour												
Livestock						year around						
Festivals		1		2					3		4	

Notes:

Secondly is short-term migration. This type of migration is a bit different from the first. These migrant workers are also unskilled laborers in the countryside. They spontaneously move far from their original commune to urban areas or the cities for seeking jobs in the companies. Their purposes are to generate income and contribute money to their families. Besides that, the short-term migrants want to get to know.

4-1-Condition before migration

Before going into the details of the research results, I would like to make a short description of the background of the labor force in Village before migration. The circumstance of migrant workers in this village is much diversified. However, they have had in generally similar socio-economic and cultural situation, so they have the relatively similar background before migration.

All of workers involved in this research are in both extended and nuclear families. However, they mostly live in the poor nuclear families with many children as well as with many brothers and sisters in the family, from two to eight children. They are those who have landless or have little land for agriculture in the village. Generally, each household was allocated 0.3 ha of agricultural land in 2004 - 2005 under the support policy of the government. The landless households are often young couples who have just

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got marriage and live separately from their parents after getting married. These couples have not been given agricultural land by their parents, because their parents have the small land area, and there are many brothers and sisters in the family. Thus, their parents want to keep that land plot for family livelihood; or the parents had sold their land to other people due to failure in cultivation before.

However, the number of employment opportunities available in the village has not met the demand of people searching for jobs, and has not resolved the unemployment status of the local people in this village. Therefore, most of the laborers moved to the nearby village to find jobs such as sorting/classifying dry "tea tree"10, mining in private enterprise, and construction work. An employee can earn about 50,000VND a day for classifying dry "tea tree", and about 70,000 to 80,000 VND a day for construction labor. In summary, the poor employees in the village are able to find jobs, but those jobs are not regular, on average, they can work five to ten days a month, and income from those works is not high. Therefore, the laborers have a lot of spare time, while they cannot create income.

4-2-Educational background

The educational background of the respondents of this research is very varied. It includes both literate and illiterate laborers. The majorities of the laborers are illiterate, and they have not completed the primary school. The illiterate laborers are primarily the middle aged and the older people. Some of the young workers had also finished secondary school. Few young labors had finished high school at grade 10 and 11. Why did not the young workers achieve higher education? That depends on two reasons: 1) their families lacked financial resources and 2) the students had a hard time to learn in school. The poor families are obliged to try to find food every day, and lack money. Moreover, in some poor families who have a lot of children, the oldest children have to take care of younger sisters and brothers when their parents go to work. Therefore, they are not able to go to school or they stop studying at an early stage. After finishing study early, the young unskilled laborers have to help their parents with the housework or find jobs in order to contribute income to the families. There are also students who are unmotivated to study, although they are supported for education by the government. Poor families do not create favorable conditions for learning. However, there are also several youths having achieved high education in college and at the University. In sum, most of the labor force has low education and they are also unemployed or underemployed, because they have not joined any vocational training courses before.

5.REASON OF MIGRATION

Many researches on migration indicate that reasons for rural-urban migration are economic difficulties, which the households face in rural areas, surplus labor force, and severe lack of employment in the rural areas. Rural people want to leave their home village in order to obtain economic opportunities through new works, especially in the big cities or developing industrial zones in the country. Besides that, rural-urban migrants want to improve their families 'economy in the rural areas by sending remittances back to the families. Similar to these points, I asked the return migrant workers who I

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encountered in the Village "why did you migrate to the city? The migrants gave many various reasons for their decision of leaving their village. Both the seasonal and short-term migrants had similar reasons for migrating to the cities. For instance, the case of Mr. S. Ph in Village was one of the typical cases.

The respondent explained that there was not much employment in the village. Although some employment is available, it has not met the demand of the employees in the village. The employment was not regular and low wage-paid. In addition, most of the migrant workers had many children. The number of family members increased (the rate of population growth in Village in 2008 was high (1.56%), according to the information source from the annual report of the village in 2008), while there were the poor households who were either landless or who had little land for production. Sources of incomes were therefore limited, and people had to seek employment elsewhere. For instance, for households with little land, in the crop season all members had to do their work in the field. When the crops finishes, they became surplus labor force in the family. Therefore, they wanted to go to find jobs and worked as on-farm and non-farm hired laborers. For the landless household, after there was no longer work in the village, they moved to other village in order to find other jobs. Moreover, together with the underdevelopment due to disadvantageous natural conditions of Village, the people were able to cultivate two rice crops per year, or one rice crop and one vegetable crop, or only one rice crop per year. Therefore, they had much spare time, while they lacked income to nourish their families. The inhabitants also presented that the productivity of rice and vegetable were low. The yield of agricultural commodities was sold in order to pay debts including agricultural materials and daily borrowing expense items, and remaining products were kept for family consumption.

The study also found that both of the seasonal and short-term migrant workers in this village mostly were able to seek jobs in the companies and in the farms due to the employment introduction of family relationship, friendship, neighbor relations, and kinship. Besides both of them also stated that there was a member family going to find job in the city in advance, and that member worked there and then called other family members to come to work in the same company or in the same farm with him/her. The migrant workers also explained that in the first time they went to the city to find the jobs, they went in groups of five or six people, most of their group heard information of employment from the oral rumor of the acquaintances. Then they went to.

6.WORKING CONDITION

As ILO (2004) and other scholars point out, the employment opportunities in the big cities, and the developed industrial zones (IZs) are the major destinations for a majority of the rural migrants. Therefore, the salary of the men employees was always higher than that of the female employees (see the table 4). When the building project was about to be finished, the workers worked very hard, about 12 hours a day, but their salaries would be increased. The working nightshift would be paid 1.5 more than normal per day; about 60,000VND to 75,000VND to the females, and 105,000VND to 135,000VND to males. In the construction company, the workers did not have to work

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extra hours. The workers would earn more money than normally if they agreed to work extra hours. The return migrant workers said that although work in the building project was harder than doing agriculture in the home village, due to hard working in the sun, but they could have much more money.

Similarly, the migrant workers in the farms had the same procedure of job application with construction workers. The migrant laborers working in farms explained that they were satisfied with the working hours in the farm. They worked 8 hours a day with 1.5 million VND a month. In rubber farm, the male employees dug the ground and planted young rubber trees. The female employees had to put the young rubber tree in the dug holes available. In the coffee farm, both of the male and female employees pick coffee beans. However, the men had to carry coffee bags after harvest. For the migrants working in the farms, their working condition was not as advantageous as the construction workers, most of them had to work in the forest, and they also faced many problems such as health problem, sanitation, and food.

7.RETURN MIGRATION OF MIGRANT WORKERS

Research of many other scholars indicated that the reasons of the returnees were very different and it was closely related to the stage of the departure of the migration. However, in terms of the situation of Iran, especially with the case of the migrant workers in Village, the study found out that the majorities of the migrant workers made decisions to migrate to find jobs out of Village spontaneously and temporarily. These migrants migrated by themselves and by the agreement of their families. The migrant workers did not think that they were permanent migrants, due to the poor current status, the migrant workers decided to migrate for economic purpose. They returned home with many various reasons. Their return migration to the village of origin was significantly related to the reasons to migrate and the expectation that the migrant workers had as well as the working and living conditions in the destination. Most of the returnee respondents had expected to find regular jobs and to have income in order to contribute to their families 'economic difficulties. These return migrant laborers mainly consisted of the poor people from the remote rural areas in the Tri Ton district, An Gilang province. They left their home village because of reasons predominantly related to the poverty in the village, to unemployment and to the low income levels in the original village.

Moreover, they also explained that it was a good opportunity for them to release tiredness after long time continuously hard working. They themselves were those who decided to return, due to lack of family labor in two crop seasons. The first rice crop was the Spring-Winter crop lasting from December to March. The second rice crop was Summer-Autumn crop from April to the middle of July. Seasonal returnees returned to the countryside at the beginning of each harvest, staying for approximately half a month. In the beginning of each production cycle, the return workers had to prepare land for seeding. After seeding rice they still stayed at home to visit and take care of their field until their rice was about ten days old, then they went back to the cities to work again in

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the same company or find jobs in another company. Moreover, during the rice harvest, the returnees went back home to help families to cut and thresh the rice.

8. SOCIAL AND ECONOMIC IMPACTS AFTER RETURN MIGRATION

After the return migrant workers re-migrated to home village, it is clear for them what it means to settle down again in their countryside. When the returnees came back, they experienced several positive and negative advantages and disadvantages which are embedded economically, socially and culturally. This part will provide a description of the different effects on each group of returnees and their families in terms of income and expenditure, social relationship and culture after their return to home village.

8-1-Impacts on social networks

There was a large variation among migrants from those who hardly had any social contacts to others, who had a large network of kin and acquaintances. Otherwise, there were returnees who had good social relations, but only with a particular social group, such as their family, or a selective group of friends, in many cases other return migrants. This research shows that a majority of return migrants in Village possessed broad social relations such as family relationship, kinship, neighbors, friendship and acquaintance/workmates and relationships with associations at the village. Moreover, there are both relations (kinship and neighbor, friendship or associations with local authority in the countryside) and there are new relationships, which they have forged at the worksite in the cities, normally workmate, and people from the same parts of the countryside as themselves. The interactions between the return migrants and other people in the community were relatively complicated. In addition, these networks of relations had two dimensions: vertical and horizontal. In addition, how were these relationships affected by the remigration of the migrant workers? I will discuss the importance of vertical and horizontal relations for finding employment in the cities for both groups of return migrants. Vertical relations consisted of relation between the return migrants and social institutions such as pagoda and local authorities. Horizontal networks conclude family relationship and kinship, which included interactions between the returnees and their family, and between the returnees and their kindred. Moreover, the other social relations such as friendship, neighbor, and acquaintances were also implanted in horizontal relations. However, these relations would be embedded in two different groups of people: returnees and villagers.

The first aspect to consider is how the return migrants regarded close kin relations. The scholars pointed out that the family relation is important for the returnees after they return their home, but there are also changes in their social relations with family because of the returnees 'migration experience. However, this study found that the majority of the returnees stated that family relations were perhaps the most important of all relations. Besides emotional aspects, the families helped the migrants to get work in the countryside, when they returned. The return to the home villages also renewed kinship bonds and made all forms of migrants aware of that their major responsibility they had was towards their own close kin. They also knew that if they would not endure the work at the assembly lines, if they lost the job, or if they became indebted their family

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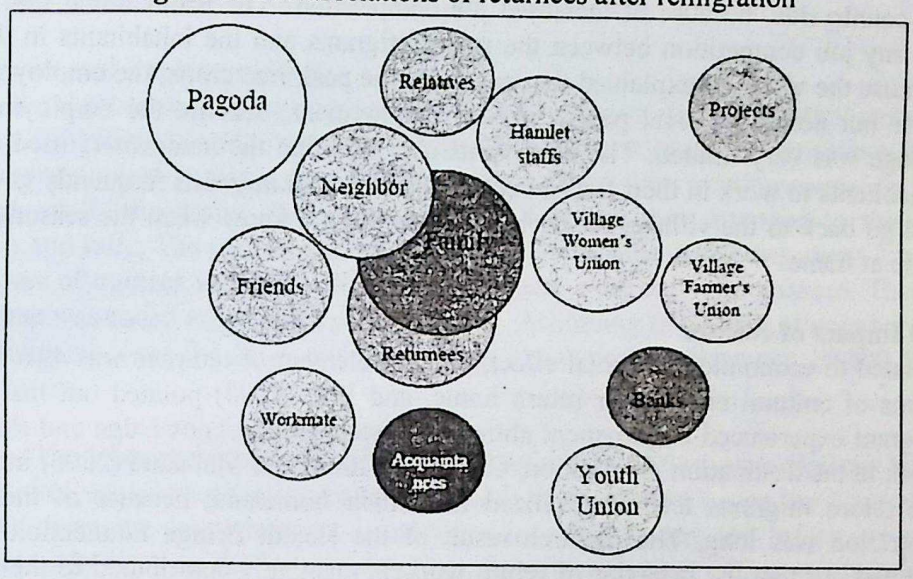
constituted their main economic and social security. The families, furthermore, functioned as a bridgehead to the neighbors in their home village, who also constituted an important part of their social networks. The returnees also said that they received the assistances of the banks and the projects, which were present in the village. However, their relationship with the banks and projects was very weak, because the returnees were beneficiaries from support programs of these organizations through the village staffs.

The last but important point, which could not be ignored, was that the returnees and villagers could find jobs by themselves. It was described that these people were not those who were very limited in their social relations, so they only had relations with the neighbor who lived near their houses. Due to lack of employment in the village, these people moved to find jobs in other neighbor communes or provinces, especially with a group including family members and neighbors.

Figure 2: Social relations of returnees after remigration



8.2 Economic impacts of remigration

Group of seasonal return migrants explained that among their families' all income sources are from agricultural production, animal husbandry, and hired labor in the countryside and in the cities or in the farms. Besides that, remittance played the most significant role for their family, because it is accumulated during time the returnees have jobs in the city and sent back home, the remittance helped to improve their family condition better than before. The remittance was used for many different purposes. Firstly, it could be used for family's daily expenses and paying debt. Secondly was to nourish old parents, children and support children's school fee. Furthermore, that money was used to buy some households appliances (mobile phone and motorcycle...) and agricultural materials (pesticide, herbicide, and fertilizer) and production tools (sprayer, baskets...). Finally, the remittances were used to contribute to monthly worship in the pagoda and construction or reconstruction in the pagoda. However, most of the seasonal

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return migrants said that their personal expenditures were reduced after back home due to low living standard in the countryside, but their family expenditures were increased due to their return home.

On the contrary, the landless seasonal returnees could generate income in the rice crop seasons. They explained that they were easy to find jobs and to work as hired labor in the village and in the neighbor villages in the peak rice crops. Although the work in the countryside was not as regular as in the city, they wanted to store rice for their family consumption, because when they were hired to harvest rice, the landowners paid them rice. However, the landless return migrants also explained that their income was lower than in the city. Some return migrants returning from the farms said that their income really decreased because they had health problems, and they had to treat their diseases. Therefore, they had not found work in the rice crop.

Will the return of migrant workers have a negative impact on available jobs in the countryside, because of increased job competition? The result found that there was not any job competition between the return migrants and the inhabitants in the village, because the villagers explained that except in the peak rice crops, the employment needs labor but normally, local people needed employment, because the employment in the village was very limited. The inhabitants also said that the landowners used to hire the inhabitants to work in their fields, because the seasonal migrants frequently go to the city and go back to the village, so the landowners did not know when the seasonal migrants were at home.

8.3 Impact of culture

Related to economic and social effect, cultural element of returnee was also affected. In terms of cultural effect after return home, and ILO (2004) pointed out that the return migrant experienced employment abroad and accumulated knowledge and skills in their work in the destination. In addition, Cassarino (2004) and Malhamé (2006) indicated that the return migrants felt marginalized from their homeland, because of their time for migration was long. The research result of the Health Bridge Foundation of Canada pointed out that the behavior of return workers positively contributed to the changes of the community of origin such as their politeness, gentleness, solidarity, cheerfulness, and their warm care. This positive issue had a direct effect on customs and lifestyles of communities with a large number of returnees, change the appearance of localities and created various services and jobs such as hospitality and small businesses. However, in the context of Village and in the particular situation of people, the study found that not only did the return of the migrants have economic and social impacts for their families and their villages, but it also affected their culture. Those changes included behaviour, lifestyle, knowledge/experience, language, and their working habits.

8.4 Re-adaption strategies of returnees

This part explores the strategies employed by both migrants and villagers concerning their adaptation strategies. The households tried to diversify their sources of income. The strategies of returnees and villagers varied according to their internal household structure in terms of size, composition, and capital. However, Malhamé (2006) indicated that after

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return the returnees faced to difficulties in their homeland such as political and job instability. Gubert & Nordman (2008) showed that the returnees'adaptation depended on their amount of money they saved during their stage of migration. According to Ha (2009), a number of return migrant workers back home from foreign countries and from the city are high, but few of them could search for employment. Some were waiting for the new chance and they would migrate to the city again, because of lack of work in the rural areas.

The study found that since the migrant workers re-migrated back home village, it can be said that employment issue was one of the most concerns of all returnees and villagers. The returnees generally could get jobs in the countryside after return, but their jobs were not regular, their income was low and unstable. They were mainly hired labor in agricultural sector. The seasonal migrant group explained that after return home they still engage in income generation activities from agricultural production. Besides their small plot of land, they find work as hired labor.

8.5 Policies and implementation

Firstly, the short-term training courses were held in order to give agricultural techniques, growing mushroom, Honda repairing, handicraft mining, sewing... There were three to four training courses within a year. For example, the short term training course on Honda repairing, at the beginning there were over 30 learners, they attended to the course seriously and fully. The course was opened during 2.5 months, but it was about 2 months, the amount of trainees was gradually decreased, there were only two trainees. Therefore, that course was ended earlier than proposed time. According to the rule of support policy, the participants were the poor, and they would be supported allowance 10,000 VND a day for meals.

The laborers lost their jobs in enterprises whose owners were fled the business in 2009: People's Committees of provinces and cities directly under the Central were borrowed from the local budgets in advance in order to pay the salary arrears for employees who were on the list of enterprises. Source of finance, which was borrowed in advance, would be reimbursed from local budget revenues due to the implementation process of enterprise assets as prescribed by law. In the case, the process of the enterprise assets was insufficient, it should be reported to Prime Minister for considering and deciding to support; the Article 3 stated that the laborers who were received support from the government had to satisfy the following criteria: the workers in the country were lost their jobs in 2009 (as stipulated in Article 1 and Article 2 of this Decision), and the workers, who worked in abroad and were lost their jobs due to business difficulties, had to return their home before the contract.

In brief, the return migrant workers did not meet the criteria as promulgated. Therefore, they had not received support of the local authorities after they returned to their home village. Most of the returnees found jobs by themselves or by the other helps such as family, kinship, friendship, neighbor, and acquaintances.

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9.CONCLUSION

This section presents the conclusion of the main findings of the study on return migration of the people in Village. Based on the literature review on migration and return migration, it was presented that the phenomenon of the internal return migration in Iran and effects of remigration on the returnees in general have not been known much. Particularly, the research on the return migration of the people in Village was carried out to answer the research questions.

First of all of the aims of this study pointed out the reasons why return migration took place in Village. The main reasons led to the remigration of migrant workers were belonged to specific situation of each migration group. Firstly, the seasonal migration group returned home because of lack of the family labor in practicing agriculture. Besides that, the seasonal migrant workers returned home due to bringing money back home and visiting home and having problem health. Secondly, the short term migration group returned home because the migrant workers could not adapt to the living condition and working condition in destinations, especially high expenditure, low income, language difficulty and pressure of working time.

Secondly, the remigration of the migrant workers affected themselves and their households positively and negatively. In terms of positive aspect, through the migration process of finding jobs and working in the companies and in the farms, the migrant workers were aware of the difficulties and their weakness in involving in the world outside their community – Village. Besides that, some of the migrant workers accessed to the modernity of the life in the city. This access and awareness will help them to have better career orientation in the future, if they want to migrate to find the jobs in the city. The next is after return their social networks were mostly broadened. This element needs to be maintained and developed in the next time. In terms of economic issue, some of the migrant workers could succeed in saving money to support their family, but mostly the migrant workers were seriously affected their income as well as of their families. Their most concerns after return home was lack of regular employment in the countryside and decrease in income sources whereas the expenditure tended to be increased. Besides the significant income reduction of the migrant workers after return home, due to particularly difficult condition of the village- lack of rural employment. This aspect also needed to be concerned and solved, particularly vocational training on vocational skills and industrial style, employment generation and employment introduction for the labor force in the rural areas in order to the poor laborers themselves as well as the next generation can guarantee their lives and have the believes in their future. Through this solution, it will contribute to the unemployment reduction in the countryside.

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EVALUATION OF ENSEMBLE STREAM FLOW PREDICTION (ESP) (CASE STUDY: ROUD ZARD DRAINAGE BASIN)

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ABSTRACT

One of the most important information which is effective in desirable utilization of water resources is the information related to predicting the future streamflow. Forecast uncertainty is one of the main issues in the utilization of forecast information to manage water resources system. The ensemble stream flow prediction (ESP) is one of the methods in considering the forecasts uncertainty. The goal of this research is to develop and evaluated monthly ESP for Roud Zard (River) basin in Iran. Two models have been used to generate ensemble traces: 1- developing a conceptual river flow model (CRFM), 2-Combining the CRFM model with the adaptive fuzzy inference system (ANFIS) and development of a hybrid model. In continuation the Event bias correction method is employed on generated ESPs and the results of the three predictions have been compared. The results show that the precision of stream flow simulation model had considerable effects in the quality of the ensemble prediction as far as average ranked probability score in hybrid model that had higher precision than CRFM model has decreased from.52 to .38 and the months with suitable prediction (positive skills score) increased from 83 to 115 months and in case of employing bias correction, there will be an increase to 119 months from the total 182 months of similar period.

Keywords: Ensemble Stream flow Prediction (ESP), rainfall Runoff model, hybrid model, bias correction

INTRODUCTION

Using streamflow prediction information is one of the oldest subjects in water resources utilization and management (Yeh et al; 1982). Many studies have been discussed the methods of employing stream flow prediction and its uncertainties in water resources system simulation and optimization models (Klemes; 1977, Stedinger et al; 1984, Georgakakos; 1989, Yao et al; 2001, Jeong et al; 2003, Kim & Palmer; 1997, Hyung, Eum; 2010). The streamflow prediction information is usually presented in three

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methods: 1- deterministic predictions, 2- probabilistic prediction and 3. Scenario based predictions. The deterministic predictions have been the traditional choice because it is simplicity but this kind of predictions does not account uncertainties. One of the methods that reduce the uncertainty is the ensemble streamflow prediction (ESP). In this method, the produced streamflow groups or clusters are base on the initial hydrological conditions in prediction time, the runoff rainfall model and meteorological scenarios. Hence, this technique has been recognized as a conditional Monte Carlo simulation method (Day; 1985). The precision of ensemble stream flow prediction is firstly related to the precision of runoff rainfall models which are used (Jeong & Kim; 2002). ESP has already become one of the active research subjects in metrology and hydrology. By the advancement of modeling methods and the current computer facilities, ESP has become the key component of the 21st century for advanced hydrology prediction services in the National Weather Service (NWS) (Schaake et al; 2004). For the first time Faber and Stedinger (2001) used ESP in weekly time step SSDP[1] optimization algorithm model. Yao et al (2001) used the ESP scenario prediction to evaluate the impacts of climate changes on dam performance. Heong Eum and Yeong O Kim (2010) studied the value of updated ESP in reservoirs management. They compared use of of conventional monthly ESP witch updated at the first of each month with an updating ESP witch update tree time a month.

In this research with respect to the absence of prepared models in producing monthly ensemble predictions, first, a runoff rainfall conceptual model was developed and its performance was evaluated by using common statistical methods. The developed model was used for simulation of the moisture conditions in the drainage basin, including soil moisture, the status of ground waters; snow coverage... in addition, a hybrid model was developed by combining the river flow simulation model with the adaptive neuro-fuzzy inference system in order to increase the precision of the model. Ultimately, by using the historical meteorological scenario, the ensemble prediction was developed by using both models for the basin subject of study and the results were analyzed and evaluated. In addition to the mentioned methods, the event bias correction method was employed on the predictions and the results were evaluated.

MATERIALS AND METHODS

To generate ensemble traces in Ensemble stream flow prediction need to a continues conceptual and physical rainfall-runoff model, the initial condition of the watershed at the forecast date(such as soil moisture, river flow and volume of reservoir reserves) and the past metrological data. In this method, the assumption is that the historical metrological scenarios could happen in future as well. In another word, they indicate the probable conditions in future. In order to make prediction in each time step, the historical metrological information along with the current conditions of basin are used as input to rainfall-runoff model in order to acquire probable flow trace. In this research, three basic methods are used to produce ensemble prediction that includes: 1. using a

[1] -Sampling Stochastic Dynamic Programming

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conceptual river flow model (CRFM), 2. Using hybrid model, 3-correction of ensemble predictions developed in second method by using event bias correction method.

- **Development of Conceptual river flow model**

The basic tool to generate ESP is a conceptual rainfall runoff model so a model has been developed in MATLAB programing language, version 2011. Developed model is a tank model and the primary calculation structure is taken similar as Nedbor-Afstromings-Model (NAM).

The conceptual river flow model (CRFM) is made of a series of relevant mathematical equations that model the ground phase of hydrology cycle. The basis of rainfall-runoff process simulation in the model is to employing the law for continuity among four linked reservoirs (each representing the different physical characteristics of the basin). The four reservoirs defined in the model include: The snow storage, surface storage, root zone storage and groundwater storage. In this model, the different component of rainfall-runoff process is routed base on continuity through four different connected reservoirs. Each reservoir represents and includes the different physical elements of the basin. The developed model could be used both for simulation of single event and continuous time series. The basic data for the model include: The model parameter, the initial conditions, metrological data and hygrometry data for calibration and validation of the model. Since the developed model is a lump model, it considers each basin as a unit; therefore, the parameters and variables indicate average value in the whole basin. Some of the parameters of the model could be obtained from the existing data and the physical conditions of the basin; however, the final parameters must be obtained through calibration in the time series of hydrologic observation. The optimization is performed automatically and by using SCE[2] method. The SCE method is a general search method particularly in finding finalized optimum. This method is designed in a way to save it from being stuck in local optimums.

- **Development of hybrid model**

One of the most important factors which affect the quality of ensemble predictions is precision of the base rainfall runoff model. In this study for lowering the errors and more consistency of the CRFM model outputs and the observed data, a hybrid model has been developed by combining the adaptive neuro-fuzzy inference system and CRFM model. In fact, the role of neuro- fuzzy model in this stage is the post-processing of the rainfall runoff model. Figure 1 shows the schematic plan of the proposed combination of CRFM model outputs and the neuro fuzzy model.

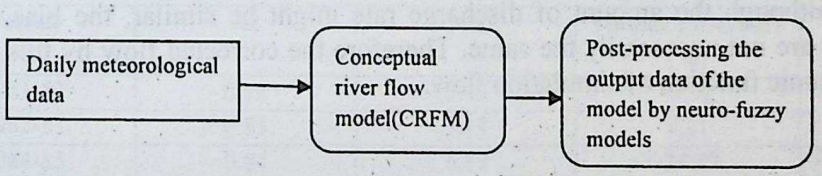

Figure 1- Schematic plan of using river flow assimilation hybrid model

[2] -Shuffled Complex Evolution

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By combining the two models mentioned above, in addition to the usage of the ability of CRFM in modeling physical processes that are effective in the river flow, the learning capability of the neuro-fuzzy model is used in simulating the existing errors in the model as much as possible.

- **The input data of hybrid model**

Since in this research, the ESP predictions are produced in monthly time intervals, the neuro-fuzzy model which is used has monthly time intervals. In order to develop the hybrid model, the inputs are classified in tow major categories:

First category: The data related to the hydrologic conditions of the basin in simulation time step, such as observed discharge, sum of rainfall of the previous time steps and the sum of rainfall in the simulation time step.

Second category: The output data of CRFM model which include different part of hydrology cycle simulation result. Here; the simulated flow is considered as an output of runoff-rainfall model.

- **Bias correction of ensemble predictions of the method:**

The method which is used in this research for bias correction of the predictions is the Event bias correction method (Smith et al, 1992). In this method, the basic assumption is that for a specific metrology scenario, there is a fixed multiplicative bias and each time this metrology scenario is used, that fixed bias should be employed for ensemble prediction of the flow. This coefficient is used without considering the initial conditions in the simulation time. Therefore, the bias correction that is employed on ensemble predictions will be as follows:

$Z^i_j = B^i_j . Ɣ^i_j$

In which B^i_j. is the bias coefficient related to the metrology scenario. $Ɣ^i_j$ is the stream flow in month J and year I. Smith et al assessed the bias correction coefficient by using the simulation data and observations in the whole historical period as follows:

$B^i_j = Y^i_j / Ɣ^j_i$

In above relations, Y^j_i is the observational river input and $Ɣ^i_j$ is the simulate input in month j and year i. the unique characteristics of this method of bias correction is that this coefficient depends only on the metrology scenario which is being used rather than the simulated flow in the ensemble predictions. As an example in the simulated flow scenarios, although the amount of discharge rate might be similar, the bias correction coefficients are not necessarily the same. Therefore the corrected flow by this method is not a monotonic function of simulation flow.

Case study:

The case study subject of study is located in southwest Iran in the east and northeast side of Ramhormoz city in the 50"-29' to 49"-38' geographic eastern longitude and 31"-44' to

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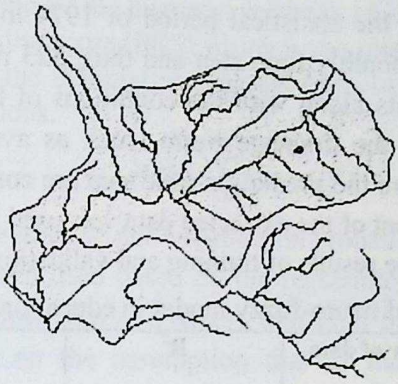
31"-06' northern latitudes. The location of the basin is shown in figure 2. In this basin, there are two rivers; *Ala* and *Zard (Roud- Rivers).*



(Figure 2- Location and map of Zard River Drainage Basin)

The range subject of study consists of more than 20 metrology statins including rain gauge that were used in the calibration process of rainfall-runoff model. There is one hygrometry station with relatively long period of observed records in the exit of basin.

RESULTS AND DISCUSSION:

- **Evaluation of conceptual river flow system**

With respect to the importance of precision of conceptual model in the ensemble predictions, first we must calibrate CRFM model. In this study we use 5 year for calibration and 6 year to evaluate the model. The statistical criteria were used for evaluating the performance. The results of calibration and model evaluation are listed in table 2 and 3; respectively.

Table 1- Results of runoff rainfall model in calibration period

Period	R2	RMSE	Volume difference (%)	Peak difference (%)
1975-76	0.88	0.98	-10.1	-32.0
1976-77	0.89	3.32	-27.46	0.62
1976-78	0.86	3.40	-9.19	2.95
1978-79	0.85	6.56	-29.9	-27.75
1979-80	0.87	7.78	7.741	-5.30

Table 2- Results of runoff rainfall model in the evaluation period

Period	R2	RMSE	Volume difference (%)	Peak difference (%)
1981-82	0.92	3.45	-7.52	-10.27
1982-83	0.85	3.11	9.31	3.66
1984-85	0.84	6.87	-24.87	-11.92
1985-86	0.82	4.86	-27.67	-14.97
1992-93	0.87	14.9	-9.26	-31.31
1995-96	0.83	12.7	-9.4	-2.8

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- **Evaluation of the performance of hybrid model:**

The aim of this study is generating monthly ensemble streamflow prediction so after simulation of the flow in the statistical period of 1974 to 2001, the outputs of CRFM model is converted into monthly time step and thus, 323 monthly data was produced in sum. The produced outputs along with the conditions of the variables that indicate the hydrologic conditions of the drainage basin, such as average discharge rate and the rainfall of the month before the prediction time step are considered as the input variables to ANFIS model. 65 percent of the extracted data was used for training and 35 percent for evaluation. Table 3 lists the results of training and validation of hybrid model.

Table 3: Results of neuro-fuzzy model in education and evaluation period

	Number of data	R^2	RMSE	Volume difference (%)
Education	217	0.90	2.9	0.11
Evaluation	115	0.94	2.59	-1.18

- **Generating Ensemble predictions**

In order to produce ensemble predictions in each time step, with respect to the initial conditions calculated by the CRFM model, including the soil moisture, snow coverage status, surface flow...the probable metrological scenarios are included in the model. In this research, the prediction horizon is taken as one month. The metrological scenarios could be produced in two ways: 1- Using the meteorological scenarios that have been produced by the different general circulation models and 2- using the historical meteorological scenarios that took place in past. In this study, we use the historical metrological scenarios and the capability of these scenarios in producing ensemble predictions was evaluated. The predictions for April, May and November to December were produced for the period of the 27 statistical years. In other months, due to no rainfall in the region and domination of the ground waters in the basin on one month and the one-month horizon in the predictions produced in this research, on the other hand, employing different meteorological scenarios into the model generates similar results and producing those predictions is not significant. As mentioned before the ESP was produced in two ways. One with the CRFM model and another with hybrid model. A limitation had been considered in using hybrid model. Since the models with the adaptive fuzzy inference systems are valid only within the training data, in conditions when the combination of the input data is beyond the validity range of the model, the CRFS model was used by itself.

- **Evaluation of ensemble predictions**

In ensemble streamflow prediction, one probability assigned to each generated streamflow trace. That probability could be acquired from theoretical statistical distributions that are made to fit on all streamflow traces and/or it can be calculated from experimental distribution. After calculating the scenarios probability, the probability of the event in different categories of the flow which is usually considered in dry, normal

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and wet modes as calculated based on observational percentiles of streamflow, is obtained. Since the ensemble predictions are probabilistic, their evaluation differs from the deterministic forecasts. One of the common methods of evaluating this probabilistic prediction is the rank probability score (PRS) which is the sum of the squared differences between the components of the cumulative forecast and observation (Wilks, 1995), as shown in the following equations.

$$P_k = \sum_{k=1}^{m} p_k,\ O_k = \sum_{k=1}^{m} o_k \quad m = 1, 2, \ldots, L \qquad \mathrm{RPS} = \sum_{l=1}^{L} (P_l - O_l)^2$$

Where p_k and O_k shows the prediction and observation probability in kth category. In this study, three category have been used based on the percentile of the flow (q) including: low flow ($q<Q_{33.3}$), normal flow ($Q_{33.3} <q<Q_{66.7}$), and high flow ($q>Q_{66.7}$). The basis of this evaluation method lies on the assumption that as the probability of ensemble prediction in a range where a real flow occurs is higher, the prediction is more précised. In a precise prediction, the probability pi will be equal to 1 and the symmetric probability of other ensemble traces events will be equal to zero. In this condition, PRS becomes equal to zero. In worst condition, the value of PRS for a three classes of flow is equal to 2 that indicate highest distance between the ensemble traces and the occurred flow. Table 4 shows the average monthly amount of PRS for the prediction took place in the Roud Zard basin. To compare the three methods of producing ensemble prediction, the skills score average has been used as follows:

$$RPSS = \frac{RPS_f - RPS_{cl}}{0 - RPS_{cl}}$$

In the above relations, PRSS is the skill score for comparing the performance of the three methods of ESP generation, PRS_f and PRS_{cl} are the rank probability score related to the prediction and the climatology. To calculate RPS_{cl} we assume equal probability for each category so the RPS will equal to 0.556, 0.222 and .554 for below normal, above normal and normal occurrence of flow. The positive PRSS values show the prediction that has skills and the negative values show the predictions with no skills. Table 4 shows the results of comparing the three ensemble prediction production methods.

Table 4- Results of average rank probability scores during the statistical period

Model / month	CRFS		CRFS-FUZZY		CFRS-FUZZY BIAS CORRECTED	
	PRS	RPSS	PRS	RPSS	PRS	RPSS
APRIL	0.43	-0.20	0.35	0.09	0.34	0.18
MAY	0.71	-0.81	0.22	0.20	0.21	0.31
NOVEMBER	0.66	-0.61	0.48	0.08	0.48	0.08
DECEMBER	0.49	-0.24	0.40	0.06	0.41	0.04
JANUARY	0.49	-0.04	0.43	0.08	0.42	0.10
FEBRUARY	0.41	0.06	0.41	0.07	0.42	0.06
MARCH	0.42	0.05	0.35	0.19	0.34	0.21
Average	0.52		0.38		0.37	
Number of months with suitable prediction	83		115		119	

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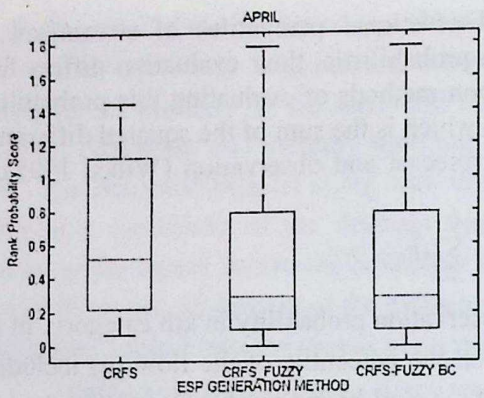

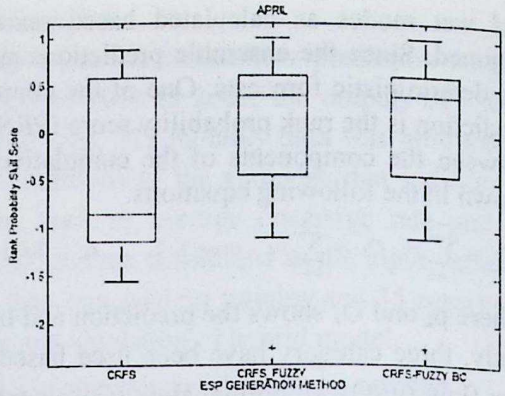

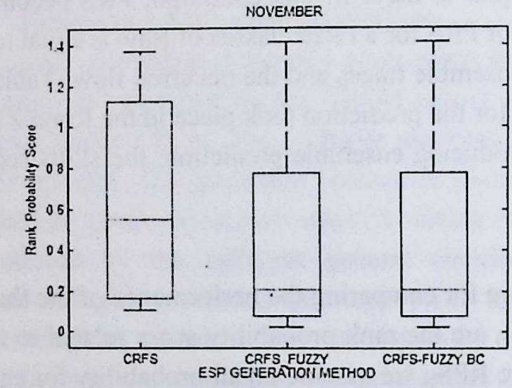

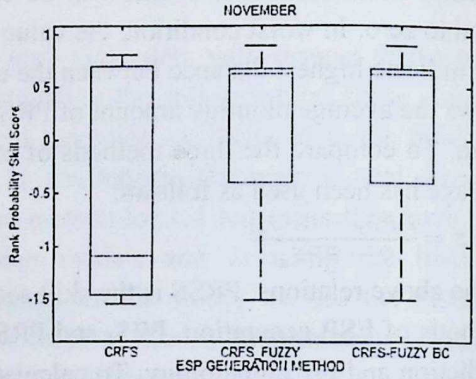

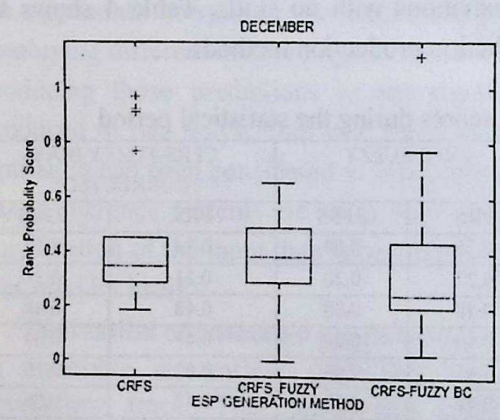

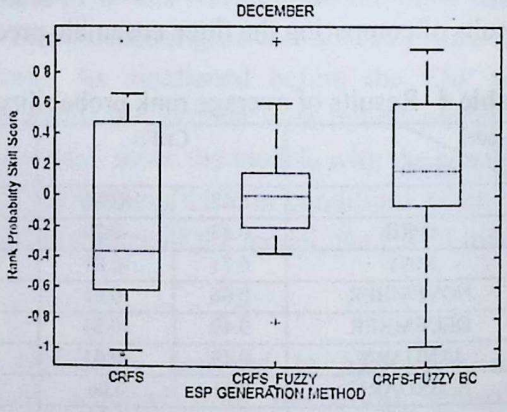

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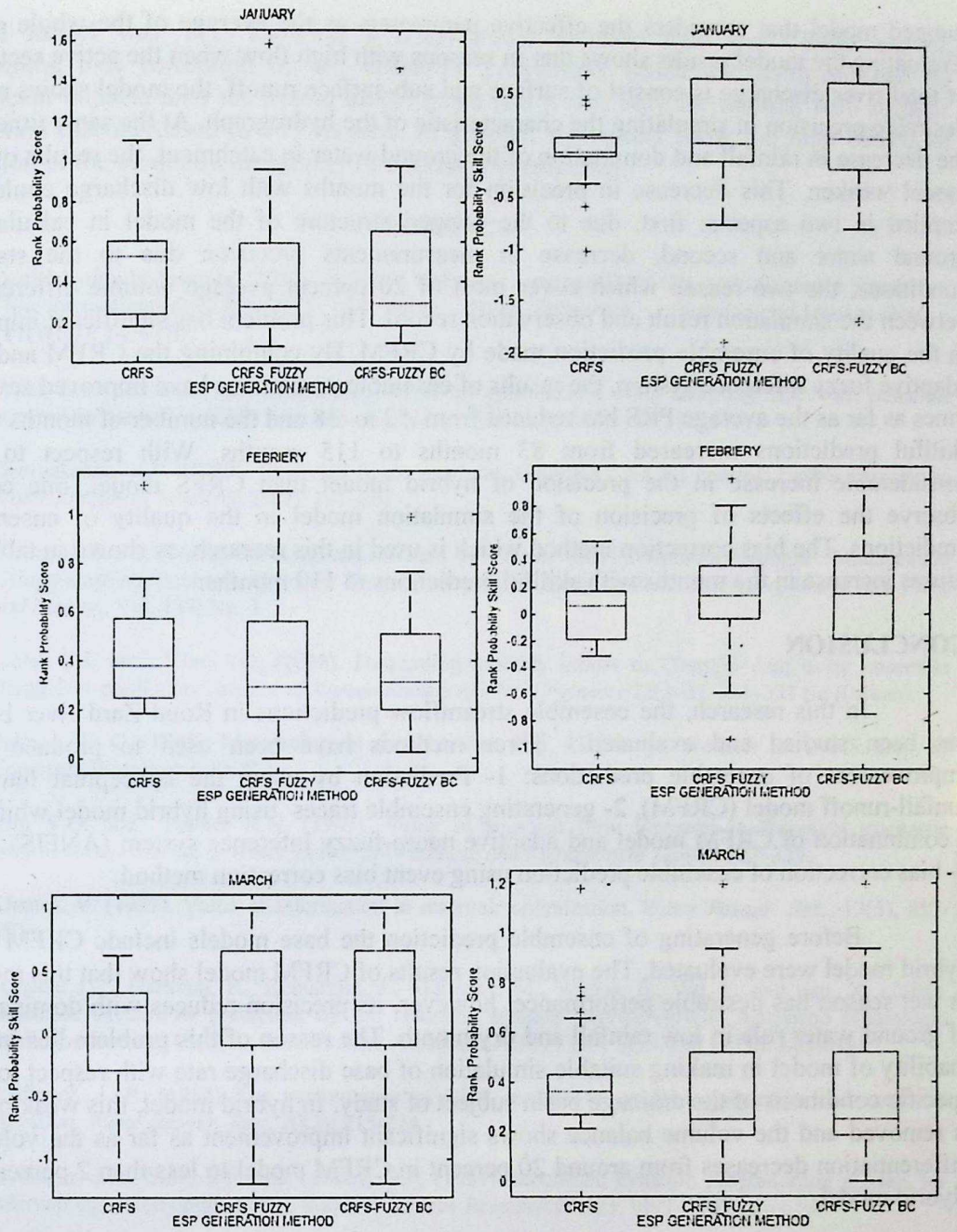

Figure 3: Box plot of RPS and RPSS for the predicted months during the evaluation period 1974-2001

As the results show, the conceptual river flow model CRFM suitable precision if it is used for ensemble predictions production. The main reason of low precision ensemble streamflow generated by CRFM model is weakness of the model to simulate low flow of the Rood Zard river basin. The rainfall-runoff model which is used in this research is a

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lumped model that considers the effective parameters as the average of the whole area. Evaluating the model results shows that in seasons with high flow when the active sections of total river discharge is consist of surface and sub-surface runoff, the model shows more desirable precision in simulating the characteristic of the hydrograph. At the same time, by the decrease in rainfall and domination of the ground water in catchment, the results of the model weaken. This decrease in precision for the months with low discharge could be implied in two aspects: first, due to the lumped structure of the model in calculating ground water and second, decrease in measurements precision due to the station conditions, the two reason which cover most of 20 percent average volume differences between the simulation result and observation record. This problem has significant impacts in the quality of ensemble prediction made by CRFM. By combining the CRFM and the adaptive fuzzy inference system, the results of ensemble predictions have improved several times as far as the average PRS has reduced from .52 to .38 and the number of months with skillful predictions increased from 83 months to 115 months. With respect to the considerable increase in the precision of hybrid model than CRFS model, one could observe the effects of precision of the simulation model in the quality of ensemble predictions. The bias correction method which is used in this research, as shown in table 4, causes increase in the months with skillful predictions to 119 months.

CONCLUSION

In this research, the ensemble streamflow predictions in Roud Zard river basin has been studied and evaluated. Three methods have been used to produce and improvement of ensemble predictions: 1- Prediction by using the conceptual lumped runfall-runoff model (CRFM), 2- generating ensemble traces using hybrid model which is a combination of CRFM model and adaptive neuro-fuzzy inference system (ANFIS), and 3- bias correction of ensemble prediction using event bias correction method.

Before generating of ensemble prediction the base models include CRFM and hybrid model were evaluated. The evaluation results of CRFM model show that this model in wet season has desirable performance; however, its precision reduces with domination of ground water role in low rainfall and dry month. The reason of this problem lies in the inability of model in making suitable simulation of base discharge rate with respect to the specific conditions of the drainage basin subject of study. In hybrid model, this weak point is removed and the volume balance shows significant improvement as far as the volume differentiation decreases from around 20 percent in CRFM model to less than 2 percent in Hybrid model.

The evaluation results of generated ensemble predictions show the intensive impact of the model precision in the quality of predictions. Evaluations with RPS and RPSS criteria show that the CRFM model all by itself has very poor performance as far as its average RPS is .56; and, the RPSS criteria is negative in most months except February and March. On the other hand, using hybrid model brings along a considerable improvement in the results as far as the RPS in it reduced to .38 and its RPSS is positive in all months. Based on the acquired results, the number of months with suitable prediction in

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hybrid model was 111, showing a considerable increase than the CRFM model. Performing bias correction on the ensemble predictions which are produced had no significant impacts than the hybrid model mode and it was only the months with suitable prediction that increased to 117 months. In general, the results show the high effects of precision of the model on the quality of ensemble predictions.

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